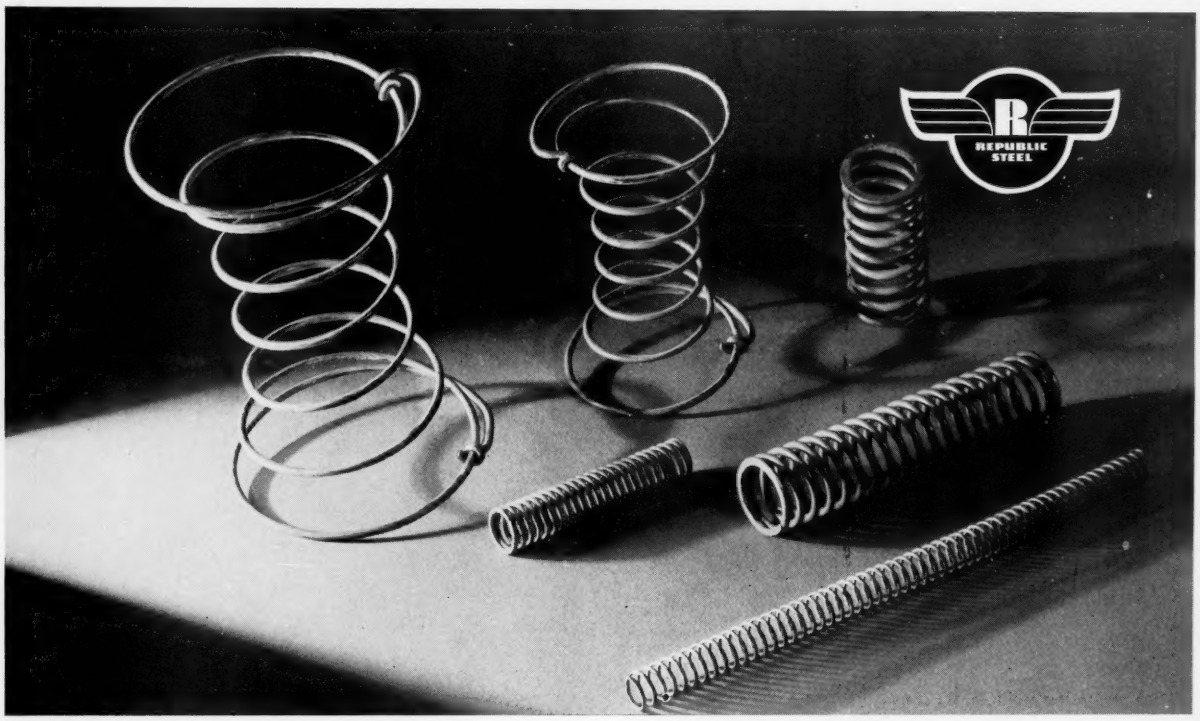
WIRE AND WIRE PRODUCTS

DECEMBER 1935



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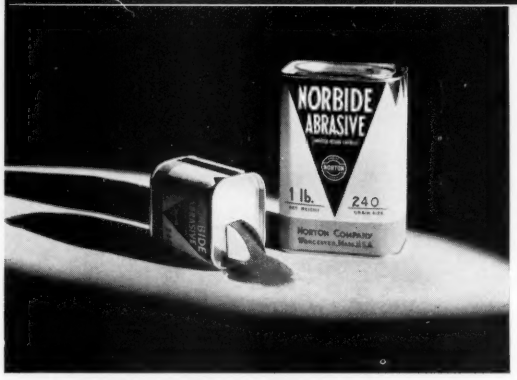

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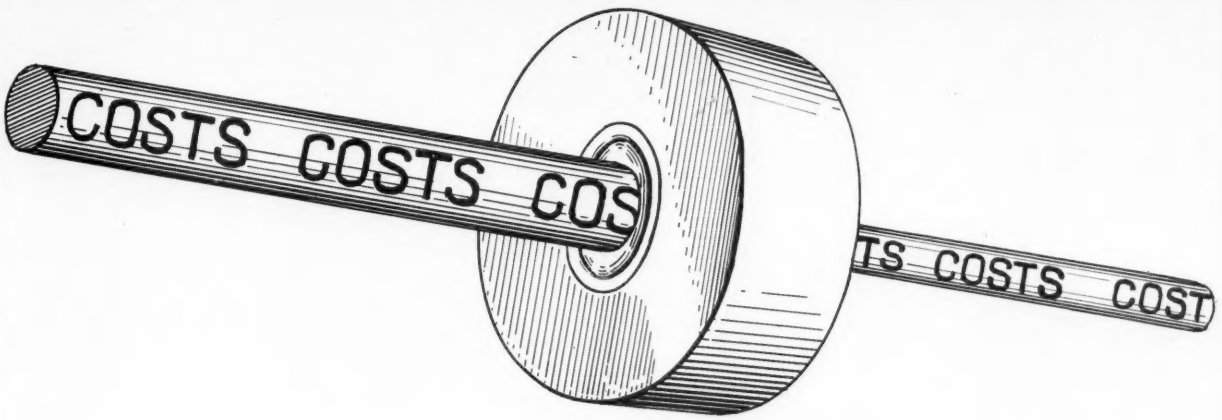

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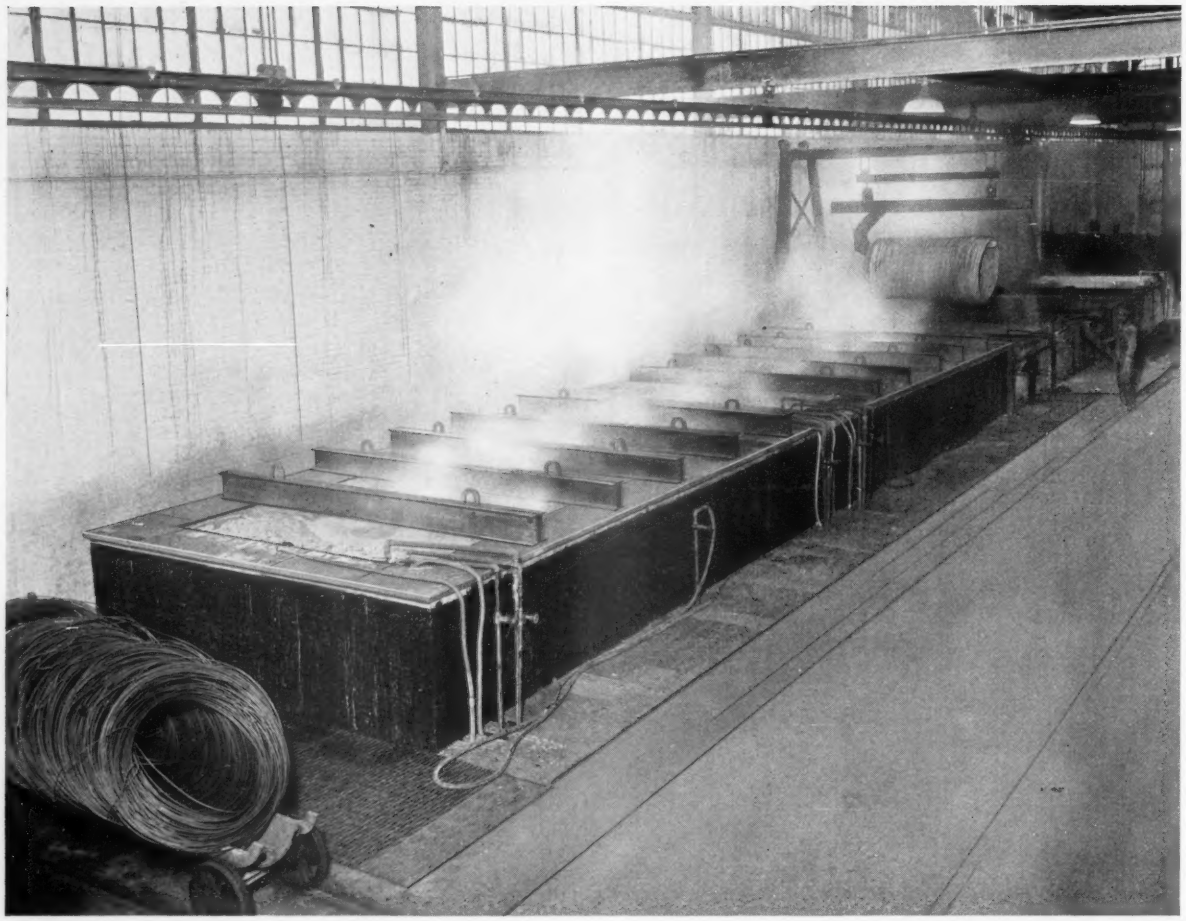

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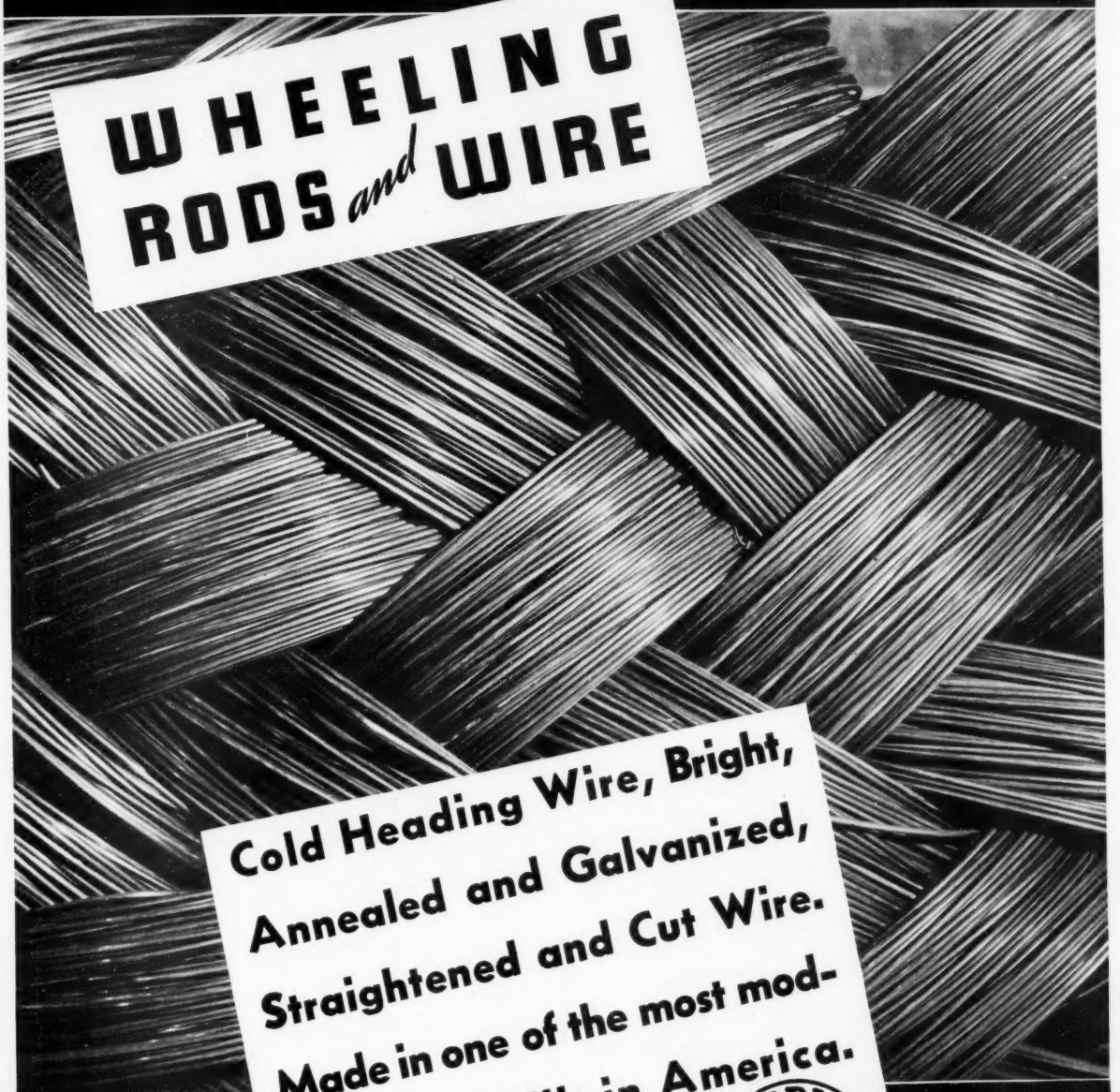

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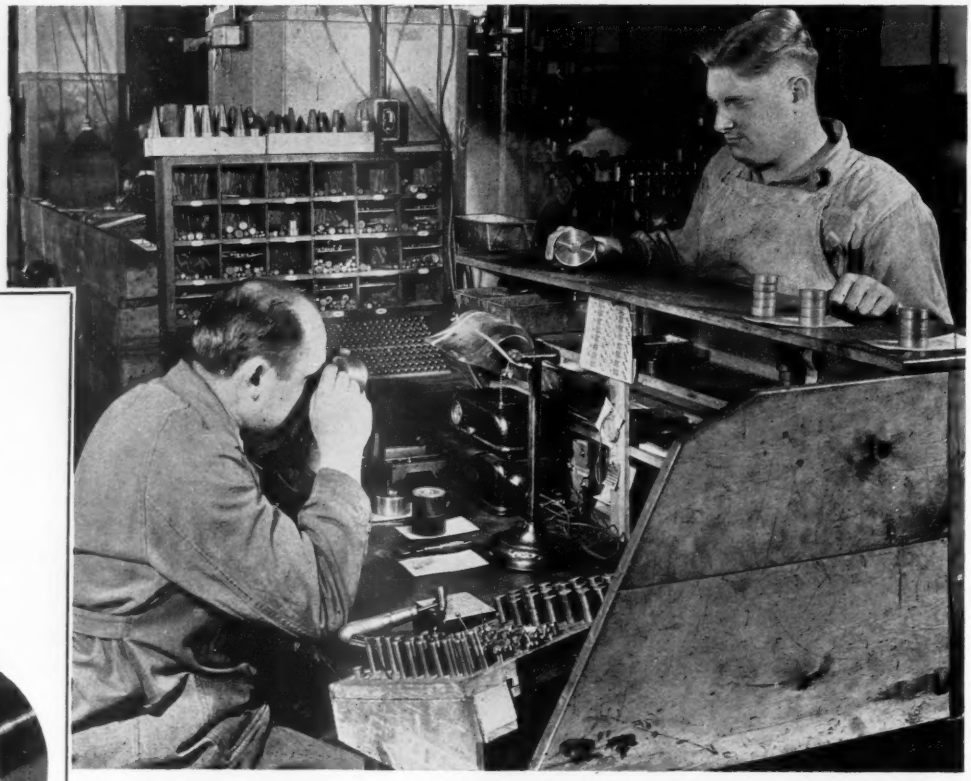

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WIRE AND WIRE PRODUCTS

A monthly publication devoted to the production of Wire, Rod and Strip Wire Products and Insulated Wire and Cable

DRAWING—ROLLING—EXTRUDING—FORMING—FABRICATING

Vol. 10 December 1935 No. 12

Designated as

Official Publication By The Wire Association

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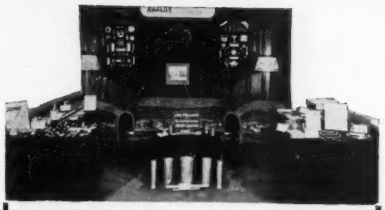

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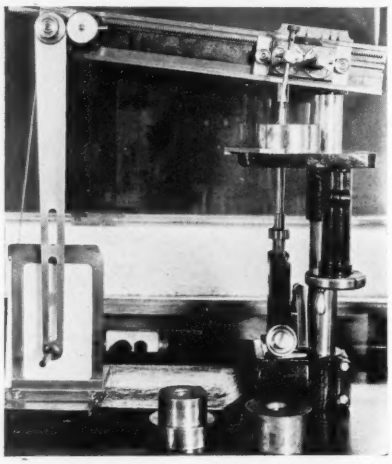

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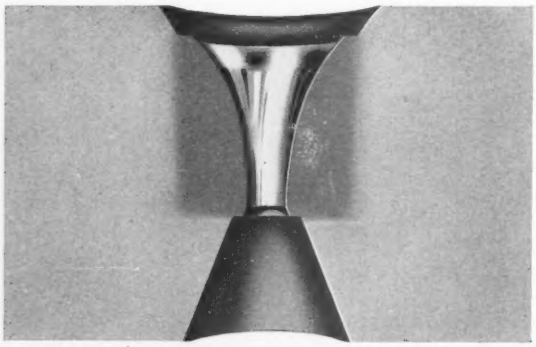

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WIRE AND WIRE PRODUCTS

A monthly publication devoted to the production of Wire, Rod and Strip.
Wire Products and Insulated Wire and Cable.
DRAWING --- ROLLING--- EXTRUDING --- FORMING --- FABRICATING

Vol. 10 DECEMBER 1935 No. 12

Wire and Cable In Aircraft Manufacture

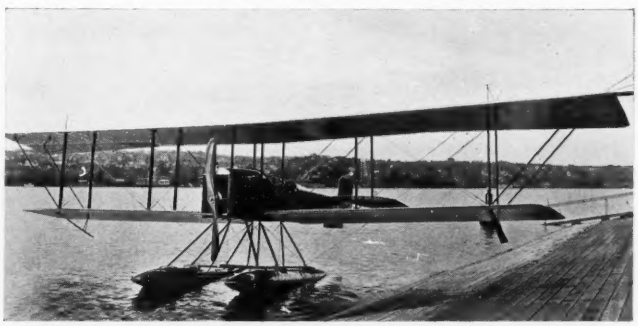
By Richard Rummell, Boeing Aircraft Company, Seattle, Washington

A summary of the uses of wire and cable in present-day aircraft together with a description of sizes, treatment of wire, and methods of installation.

THE famed "stick and wire" airplane of the War and immediate post-War period long since has vanished from the aviation picture. Metal has come to displace both wood construction and wire bracing until the 1935 plane is a marvel of integral all-metal construction, with cantilever-type wings and tail surfaces and without either external or internal wire bracing. Yet despite the fact that cable and wire no longer are called upon to hold the airplane's structural parts together, those two items continue to have an important place in aircraft manufacture.

✦ ✦ ✦

PROBABLY at no place could the subject be studied to better advantage than at the plant of the Boeing Aircraft Company, Seattle, Wash., one of the world's leading producers of both commercial and military planes. In its nineteen years, this factory has turned out more than 1900 planes of sixty different types. High-speed twin-engined Boeing transports of United Air Lines and other operators, flying overnight from coast to coast and border to border, are covering approximately 60,000 miles every twenty-four hours. Boeing single-seater pursuits and fighters daily are operating at Army Air Corps bases, Navy and Marine shore stations, and on and off the Navy's aircraft carriers.



IT WAS "MODERN" IN 1916: The first Boeing plane of nineteen years ago—a "stick and wire" type seaplane trainer which had a top speed of around sixty miles an hour. Note the struts and wires then employed, as contrasted with the clean, unimpaired lines of the latest Boeing transport. (See next page). ✦

✦ ✦ ✦

Uses For Wire and Cable in Aircraft

WHEREVER they fly, these planes are depending to a large extent on high-strength cables for sure and effective control; on wire for lighting, for radio equipment, for the ignition system, etc. Literally miles of both cable and wire go into some of the giant multi-motored commercial transports and military planes which feature present-day aircraft manufacture.

✦ ✦ ✦

Each Plane Requires About Two and a Quarter Miles of Wire and Cable

ALTOGETHER, the Boeing Company has delivered seventy-five of its latest Model 247-type transports to air line operators in this country and abroad. Into each one has gone 2592 feet of preformed cable and electric wire. Thus, a total of 194,400 feet or the equivalent of thirty-seven miles of cable end wire has been used in the entire project. Two and a quarter miles of such material went into a single plane recently produced by the company!

✦ ✦ ✦

Cable Uses

CABLE is used chiefly for control connections leading from the pilots' compartment to the control surfaces. High strength and flexi-

Designated as Official Publication by the Wire Association

High Carbon Steel Wire Uses

HIGH strength carbon steel cable, with a variety of strandings—depending on the purpose for which it is designed—is employed. In cases where flexibility is not a major requirement, 1 x 19 cable is used. For utmost flexibility, 7 x 19 is resorted to. A happy medium for both strength and flexibility is 7 x 7.

✦ ✦ ✦

CABLE sizes for controls range from 1/16 to 3/16 of an inch. In Navy planes, 3/8 inch cable has been used for hoists.

✦ ✦ ✦

Installation Methods

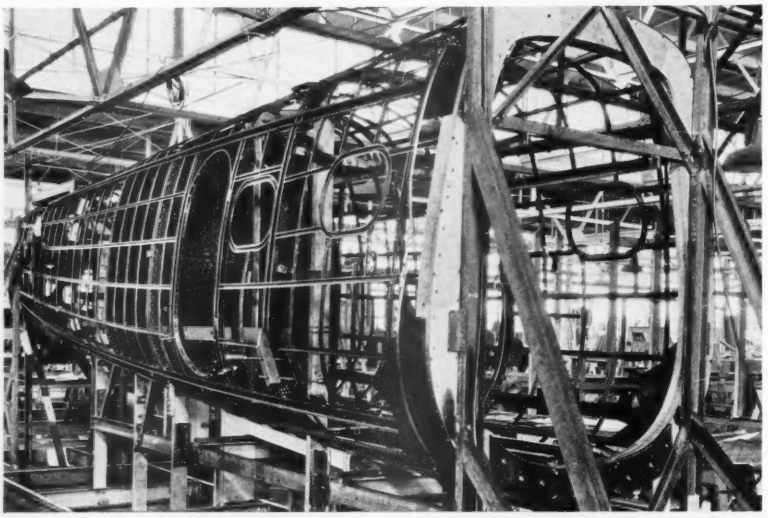
THE method of installation varies, according to the purpose which the cable is to serve. In some cases, it is tied into turnbuckles; in others, it is connected with bushings and fittings. Control cables work through fibre fairleads and over micarta pulleys.

✦ ✦ ✦

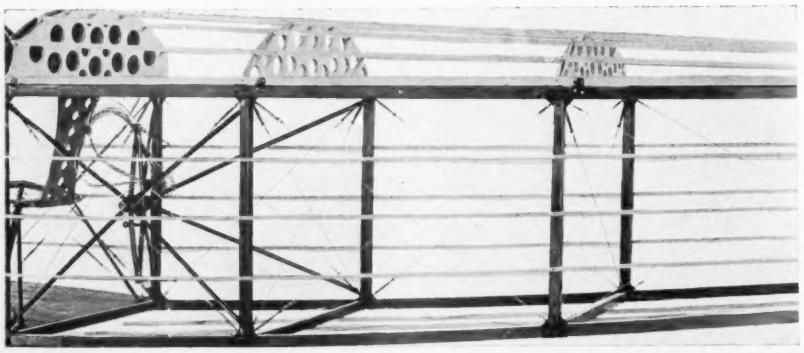
Testing Wire and Cable

ALL cable is proof tested to sixty per cent of its specified breaking strength before installation in Boeing planes. The breaking strength of 1/8 inch preformed 7 x 19, such as is used in the operation of control surfaces, is 2000 pounds, minimum. That of 1/16 inch 7 x 7, such as is employed for motor controls, shutters, etc., where no strain is imposed, is rated at 480 pounds. The rated breaking strength of 1/8 inch regular 7 x 7 is 1350 pounds, and that of 5/32 inch preformed 7x19 is 2800 pounds.

A 1935 AIR LINER: The Boeing 247-D high-speed twin-engined transport, such as is used by United Air Lines and other operators in this country and abroad. Equipped with two 550-horsepower supercharged Wasp engines and with controllable pitch propellers, this plane has a top speed of 202 miles an hour and cruising speed of 189 miles an hour while carrying a full load of ten passengers, two pilots, stewardess, baggage and cargo. Retractable landing gear and cantilever-type surface, as contrasted with the fixed landing gear and external bracing used in the old days, contribute to the transport's clean appearance. ✦ ✦ ✦ ✦



AIRCRAFT CONSTRUCTION, 1935: The integral all-metal type of construction used in producing present-day Boeing commercial and military planes is disclosed in this view of the rear body section skeleton of a high-speed, twin-engined Boeing transport. Duralumin, an aluminum alloy strong as steel but only one-third as heavy, is used for the skin stiffeners, bulkheads, longerons and outer skin covering. ✦ ✦ ✦ ✦ ✦ ✦ ✦



AIRCRAFT CONSTRUCTION, 1916: Typical "stick and wire" construction such as was used in airplanes during and immediately after the World War is illustrated in this view of the fuselage structure of the first Boeing plane, known as the "B & W". Wood was used for the framework, with cable and piano wire for bracing. ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦

✦ ✦ ✦

Electric Wiring

ELECTRIC wiring going into Boeing planes is of the stranded soft copper type, insulated with treated cambric and covered with double cotton braid. Sizes range from No. 20 to No. 2. Wire is used for instrument board lighting, cabin lights, the engine ignition system, main battery leads to starters, landing lights, navigation lights, call bells, two-way radio telephone connections, etc.

✦ ✦ ✦

The Cable Shop

BOTH cable and wire are handled by the Boeing Company's well-equipped cable shop, which normally employs fifteen men, including the foreman, cable splicers, cable workers and electricians. No cable or wire drawing is done by this department, with splicing as the principal activity. Splicing jigs, marlin spikes, end cutters, pliers, wood mallets and anvils make up the splicers' equipment. Admiralty

AND HERE'S WHERE IT'S DONE: In the cable shop of the Boeing Aircraft Company, where expert workers handle the miles of cable and electric wire used in both commercial and military planes. As in all the company's other shops, craftsmanship and quality are the watchwords of the fifteen men normally employed in this department.

splices are used, according to Army Air Corps, Navy and Department of Commerce specifications. Thirty-two splices a day is considered a good average for a worker.

✦ ✦ ✦

Inspection Service

THE skilled work of the cable shop is typical of that accomplished throughout the Boeing factory organization. Quality comes first, last and always, from the time a plane is designed until it goes into the air. Expert and vigilant inspectors go over material at each stage of its fabrication. Some parts are examined as many as twenty times before final approval. One hundred per cent inspection is the order for everything from rivets to major assemblies.

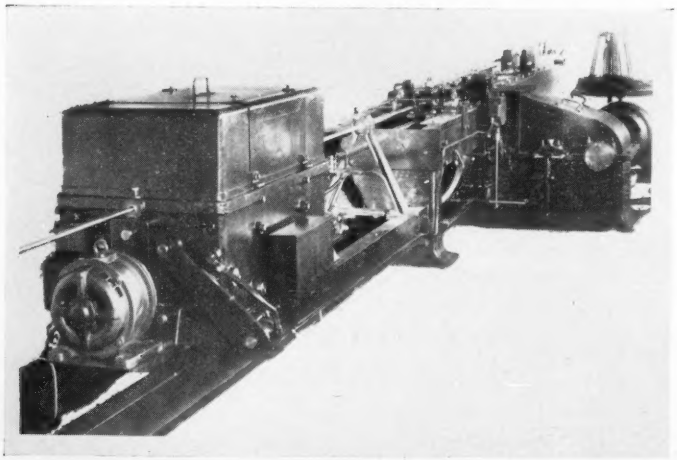
✦ ✦ ✦

AT the same time, the Boeing Company does not leave strength factors to conjecture. Complete and thorough stress analysis of every part is made in the course of design. Then, before quantity production gets under way, static, dynamic and vibration tests are employed to prove the strength factors of structural parts. The Army, the Navy and the Department of Commerce have their stringent specifications in every case. The Boeing Company demands that these specifications not only be met; in a great many cases the requirements are exceeded.

✦ ✦ ✦

WHEN a plane at last is given final approval, it definitely is ready to do its job, whether it be in the service of the Army or Navy, or on the commercial air lines of the country. And in whatever that plane does, cable and wire contribute not a little to its accomplishments.

New Machine For Producing Straight And Polished Rods In A Single Operation



A NEW, patented combination machine for the manufacture of drill rods, screw machine rods, brass and alloy metal rods of ⅛-1 in., diameter, has been brought out by the engineering firm of "Schumag", Aachen, Germany. Steel coils coming directly from the rolling mill, or brass coils coming directly from the extrusion press, are converted by this machine in a single operation and with one operator into straight and polished rods.

✦ ✦ ✦

THE machine does preliminary straightening of the coil material, drawing or reducing to size, cutting to length, and straightening and reeling or polishing. The

(*Please turn to page 595*)

The Correlation of Spring-Wire Bending And Torsion Fatigue Tests

By Prof. E. E. Weibel,
University of California, Berkeley, Calif.

Contributed by the Research Committee for presentation at the Annual Meeting of The American Society of Mechanical Engineers to be held in New York, N. Y., December 2 to 6, 1935. Publication authorized by A. S. M. E. Technical Committees. ✦ ✦

The investigation reported in this paper was an attempt to correlate bending and torsion fatigue results for tempered Swedish valve-spring wire so that the torsion fatigue strength might be inferred within reasonable limits of accuracy from the fatigue values found in the simpler rotating-beam test. The original program called for (a) the development of suitable methods of gripping the wire for the torsion fatigue tests; (b) the determination of bending and torsion fatigue values for one size of wire in the as-received condition, and also after removal of the surface layer in a centerless grinder; (c) the determination of fatigue values for other sizes of wire between ⅛ in. and ¼ in., as permitted by time limitations; and (d) a survey of the literature for data bearing on the correlation of bending and torsion results. The results of these experiments on straight specimens of tempered Swedish wire in torsion and bending fatigue may be summarized as follows:

1. **Methods of gripping were developed which are satisfactory for both bending and torsion fatigue tests with the exception of torsion tests on shot-blasted wire.**
2. **Zero to maximum torsion fatigue values for straight specimens in the as-received condition were about 70 per cent higher than values estimated from previous tests on carefully coiled springs.**
3. **The smaller of two sizes of wire tested in the as-received condition had the higher torsion fatigue limit and lower ultimate torsional strength.**
4. **Removal of the natural surface by grinding increased the bending fatigue strength about 20 per cent, but decreased the torsion fatigue strength about 4 per cent.**
5. **Shot-blasting increased the bending fatigue strength about 27 per cent and increased the torsion fatigue strength an undetermined amount.**
6. **The zero-to-maximum torsion fatigue limits of two sizes of wire tested in the as-received condition were 1.5 and 1.6 times their respective bending fatigue limits.**
7. **For two sizes of wire in the as-received condition the values of 0.84 and 0.90 were obtained for the ratio of reversed torsion fatigue strength to reversed bending fatigue strength.**
8. **Approximate measurements of surface residual stress were made on the wire in different conditions before and after fatigue testing and before and after coiling, which may have a bearing on the fatigue properties of springs.**

I—Review of the Literature Methods of Gripping Wire in Torsion Fatigue Tests

A DESCRIPTION of gripping methods satisfactory for torsion fatigue tests on tempered carbon-steel wire could not be found.

✦ ✦ ✦

F. C. Lea of Sheffield has developed methods of gripping which are satisfactory for cold-drawn wires. In his earlier work (1)[2] split bushings were used. These were not entirely satisfactory for tempered wire. In his later work (2) gripping shanks of an alloy with a low melting point (type metal) were cast on the ends of the wire specimen. It was found that 80 per cent of the cold-drawn-wire specimens failed at a distance from the grips.

✦ ✦ ✦

GOODACRE (3) reviews gripping methods in use in England for bending, tension, and torsion fatigue tests on ferrous and non-ferrous wires. In the case of torsion Lea's casting method is mentioned.

✦ ✦ ✦

A STUDY of type-metal alloys by F. D. Weaver (4) was noted; also a paper by L. J. G. van Ewijk (5) on the penetration of steel by soft solder and other molten metals at temperatures up to 400 C. The latter's observations may explain why Lea's casting method, unmodified, was not successful with tempered Swedish wire.

✦ ✦ ✦

IN 1929, O. Föppl (6) obtained increased torsion and bending fatigue strengths of polished specimens by rolling the surface so as to produce local plastic flow.

✦ ✦ ✦

[1] Instructor in Department of Mechanical Engineering, University of California. Dr. Weibel received the degree of B.Sc. in mechanical engineering at McGill University, Montreal, in 1918. During the summers, 1915 to 1917, he was employed as structural draftsman with the Dominion Bridge Company, Ltd., Montreal; and from 1918 to 1922 as mechanical designer and estimator on steam-turbine and electric-crane work. From 1922 to 1927 he was supervisor, under the mechanical engineer of the company, of the mechanical-design squad on cranes, hydroelectric regulating gates, etc. During 1928 and 1929 he studied mathematics at the University of Toronto and in 1929 returned to the Dominion Bridge Company where he was employed on mechanical standardization and as field engineer on the installation of hydroelectric equipment. In 1931 Dr. Weibel received the M.S.E. degree and in 1932 the degree of Ph.D. in engineering mechanics from the University of Michigan where he specialized in photoelastic stress determination. At the time these tests were carried out Dr. Weibel was research associate in the engineering research department of that University.

[2] Numbers in parentheses correspond to similarly numbered references given in the bibliography at the end of the paper.

A PUBLICATION by P. Behrens (7) describes the rolling apparatus used by Föppl, and gives further results. An increase of 17 per cent in torsion fatigue strength of a mild steel was obtained, and increases of 20 to 50 per cent in bending fatigue strength of a low-carbon steel.

✦ ✦ ✦

THUM and Wunderlich (8) determined the bending fatigue strength of shafts with and without a press-fitted collar. Heavy stress concentrations, microscopic rubbing with the formation of oxides and corrosion, lowered the fatigue strength considerably. By surface-rolling the shaft and shaping the collar to reduce stress concentration, an increase of 95 per cent in fatigue strength was obtained.

✦ ✦ ✦

A PAPER by O. J. Horger (9) presents a considerable amount of data on the surface-rolling process. Increases in bending fatigue strength around 30 and 40 per cent were obtained. Petersen and Wahl (10) also experimented with surface-rolling. Their paper includes a summary of Thum and Wunderlich's results.

✦ ✦ ✦

Fatigue Results on Tempered Swedish Valve-Spring Wire

SWAN, Sutton, and Douglas (11) tested straight specimens of a tempered Swedish valve-spring wire in torsion fatigue with maximum stress four times the minimum stress. When tested at full diameter of 0.128 in. the safe range was from 20,200 to 80,800 lb. per sq. in. When reduced to 0.100 in. diameter and polished, the safe range was from 31,400 to 125,500 lb. per sq. in., an increase of 56 per cent. These stress values were not measured directly but were assumed proportional to the angular travel of the gripping chucks, an assumption which will be shown later to be unjustified because of variations in the effective length of the specimen.

✦ ✦ ✦

F. P. ZIMMERLI (12) tested a number of steels in the form of completed springs. The steels, numbers 4 and 7, were straight carbon pretempered Swedish wires, 0.148 in. diameter, with 0.75 and 0.65 per cent carbon content, respectively. The safe ranges decrease with increasing mean values of torsion stress in close agreement with the Goodman diagram. Probable values of zero to maximum torsion stress range extrapolated from the diagrams are 68,000 and 58,000 lb. per sq. in., respectively.

✦ ✦ ✦

BENDING fatigue tests were made on two sizes of Swedish valve-spring wire by Shelton and Swanger (13). The first wire, 0.162 in. diameter, 0.65 per cent carbon, had an ultimate tensile strength of 221,000 lb. per sq. in. and with the natural surface a fatigue strength 34 per cent of the ultimate, or ±76,000 lb. per sq. in. When reduced to 0.130 in. diameter and polished, the fatigue strength was 56 per cent of the ultimate or ±126,000 lb. per sq. in. The second wire, 0.148 in. diameter, 0.65 per cent carbon, had an ultimate strength of 217,000 lb. per sq. in. and a fatigue strength only 30 per cent of the ultimate or ±65,000 lb. per sq. in. It showed surface defects.

✦ ✦ ✦

Other Fatigue Results

THE torsion fatigue results of G. A. Hankins (14) on polished specimens of spring steel show safe stress ranges which are practically the same for alternating torsion and for zero-to-maximum torsion stress. For higher mean stresses there is a reduction in the safe range but values are always greater than would be given by the Goodman diagram.

✦ ✦ ✦

The Correlation of Torsion and Bending Fatigue Results For Wire

NO reports of experiments were found in which torsion and bending fatigue results were obtained for the same wire and compared. Considerable experimental work and some theoretical work having a bearing on the torsion fatigue strength and on the ratio of torsion to bending fatigue strengths was reviewed.

✦ ✦ ✦

A CRITERION of fatigue failure of metals under any type of stress does not appear to have been found. Fahrenhorst and Schmid (15) review briefly the hypotheses as to the cause of fatigue failure of Kuntze, Haigh, Ljungberg, Ono, Ludwik, Gough, Hanson and Wright, and Schmid. These are many and various and will not be given here.

✦ ✦ ✦

H. J. GOUGH (16) reported that behavior of metals was being studied under reversed bending, reversed torsion, and all possible combinations of these two types of fatigue loading. Mild steel, a ductile material, obeyed closely the distortion-energy theory of von Mises and Hencky and discussed in a paper by Nadai (17), according to which theory the safe torsion fatigue stress would be 0.577 times the safe bending fatigue stress. But an alloy steel and a cast iron exhibited other relations. He concludes that no general criterion of failure obtains under the stated stress conditions.

✦ ✦ ✦

FATIGUE experiments by A. F. Maier (18) on tubes under two types of reversed stressing obtained by means of internal pressure appeared to support the theory of maximum shear stress according to which the safe shear stress is 0.500 times the safe tensile stress. The results did not support the distortion-energy theory.

✦ ✦ ✦

MOORE and Kommers (19) list the reversed-torsion endurance limits and the reversed-bending endurance limits for polished specimens of a number of straight-carbon steels which had received widely different heat-treatments. The average of 19 values of the ratio of torsion endurance limit to bending endurance limit was 0.55. Extreme values were 0.48 and 0.64. The average of 49 values of the same ratio, from results of tests on polished specimens, listed by Gough (20), was 0.56. Extreme values were 0.44 and 0.80. These results are for presumably homogeneous and isotropic material, and surface effects have been eliminated as far as possible.

GILL and Goodacre (21) studied some aspects of the fatigue properties of patented wire. They found that wire with decarburized surface will take overloads as well as, or better than, wire not decarburized and conclude that there is no gain in removing the decarburized surface if wire will be overstressed much. The writers assume that the ratio of torsion fatigue strength to bending fatigue strength should have the value $^2/_3$, and using this value together with one of their bending fatigue results for polished wire, they calculate a hypothetical torsion fatigue strength which agrees closely with a previous experimental torsion fatigue value for polished wire obtained by Lea and Dick (22). They say, "It seems very probable therefore that the fatigue limit in bending will give a good indication of the torsional fatigue properties of polished spring wire." But they give no reasons why it should and offer only one sample calculated value, and do not check experimentally the torsion strength of the actual wire whose bending fatigue strength they used in their calculations. The arbitrary use of the ratio $^2/_3$ did not appear to be justified.

✦ ✦ ✦

VALUES of stress concentration factor around spherical and cylindrical inclusions have been given by Southwell and Gough (23) and J. N. Goodier (24), and the stresses around an elliptical hole in a plate by C. E. Inglis (25).

✦ ✦ ✦

GOODIER shows that the elastic stress concentration factors at a small spherical cavity in regions of uniform pure shear and of uniform tension stress are 1.91 and 2.72, respectively. These values cannot be used in estimating the effect of such a cavity on fatigue strength in the two cases, since the first is in terms of maximum shear stress, and the second is in terms of maximum tensile stress. From Goodier's results it can be shown that for a cavity in a field of uniform tension stress, the maximum shear stress is increased just 1.91 times. If fatigue failure were known to be determined by maximum shear stress, this would lead to the practical conclusion that the ratio of torsion endurance limit to bending endurance limit is unaffected by the presence of small spherical inclusions which are not too close to the surface.

✦ ✦ ✦

SINCE in wire, inclusions are probably lengthened out as a result of drawing, calculations for ellipsoidal cavities would be of interest, but none were found in the literature.[3]

✦ ✦ ✦

FOR flaws at the surface of wire, the two-dimensional elastic stress concentrations for circular and for elliptical cylindrical holes might be applied assuming again an arbitrary criterion of fatigue failure. At a minute circular hole in the surface of the wire, for the case of torsion, the maximum shear stress is doubled, and for the case of bending, the maximum shear stress is trebled (24). Therefore, such a flaw is more effective in reducing the bending fatigue strength than in reducing the torsion fatigue strength.

✦ ✦ ✦

STILL assuming the maximum shear stress criterion, we may consider the elastic stress concentration factors for an elliptical flaw on the surface with major axis placed longitudinally and four times the length of the minor axis. For the case of bending, Inglis' formula gives a factor of 1.5. For the case of torsion, the maximum shear stress is increased by the factor $[1+ (a/2b) + (b/2a)]$, where a and b are the major and minor semiaxes, respectively. This formula is not given by Inglis, but was obtained from his results. The value of the factor in the present instance is 3.12. Hence, it is seen that a longitudinal elliptical surface flaw will reduce the torsion fatigue strength proportionately more than it will the bending fatigue strength. Numerical comparisons are limited by the lack of numerical values for notch sensitivity of the material, but it is apparent that any attempt to calculate the torsion fatigue strength from the bending fatigue strength must take account of the shape of flaws which are permitted by the specifications. A striking example of the formation of four fatigue cracks at the points of stress concentration around an approximately elliptical flaw of a torsion fatigue specimen is shown in Fig. 27.

✦ ✦ ✦

DIFFERENT materials under alternating loading react differently to stress concentration.

✦ ✦ ✦

W. BUCHMANN (26) concludes that "Notch sensitivity is a utilizable property of the material, determinable by calculation." This is the same quantity which R. E. Petersen (27) calls "stress concentration index" q where

$$q = (k - 1) (K - 1)$$

where k is the ordinary endurance limit without stress concentration divided by the endurance limit with stress concentration (fillet, hole, etc.), and K is the elastic stress concentration factor and is equal to the maximum stress at a fillet or hole divided by the average nominal stress.

✦ ✦ ✦

W. BUCHMANN (26) made fatigue studies in bending and torsion on specimens about 0.3 in. diameter, with circumferential notches of 0.002 in. to 0.08 in. radii. Fatigue strength of annealed materials was practically unaffected by the presence of the notch (q practically equal to zero for very ductile materials), while for hardened steels the reduction in fatigue strength was practically proportional to the calculated increase of stress at the notch (q approximately unity for very brittle materials). For the same material the greatest difference between actual reduction of fatigue strength and reduction calculated from the elastic stress concentration factor occurred with the sharpest notches (q decreases with increased sharpness of the notch in a particular material).

✦ ✦ ✦

ERICH SCHEIL (28) published a paper on the origin of cracks in steel as a result of heat-treatment, and found a dependence on

[3] A paper by H. Neuber has since been noted, "Der Raümliche Spannungszustand in Umdrehungskerben," **Ingenieur Archiv**, vol. 6, No. 2, April, 1935, p. 133.

the internal-stress condition, the separation strength of the steel, and other factors.

✦ ✦ ✦

THE effect of internal stresses on fatigue strength were studied by Buehler and Buchholtz (29), who worked with specimens about 1 in. in diameter. They found that compressive surface stresses of about 30,000 to 50,000 lb. per sq. in. caused by quenching, raised the bending fatigue limit from 10 to 20 per cent. They quote results which show that large tensile surface stresses reduce the fatigue strength about 15 per cent, and that tensile stresses below 28,000 lb. per sq. in. have no appreciable effect on fatigue limit. They mention the gradual reduction of internal stresses as a result of fatigue stressing.

✦ ✦ ✦

THE same authors (30) studied the relation between residual temperature stresses and yield point of the material and found higher residual quenching stresses for materials with lower yield point due to the greater amount of plastic deformation which occurred during quenching.

✦ ✦ ✦

BUEHLER and SCHEIL (31) studied the combined effect of temperature and transformation stresses in 2-in. diameter specimens of quenched steels. The nickel content was varied to give various transformation temperatures corresponding to different carbon content in straight-carbon steels. Lower transformation temperatures left tension stresses at the surface. Very high transformation temperatures left compressive stresses. Smaller-diameter specimens had smaller tension or compression surface stresses than large-diameter specimens.

✦ ✦ ✦

LINICUS and SACHS (32), in studying the effect of the die angle and degree of drawing on the internal stresses in wire, measured the internal stress by planing off half the width of the wire and noting the change of curvature. However, this gave only a qualitative measures of stress.

R. M. BROWN (33) in measuring residual stresses in cold-drawn mild-steel rods, found that in general, zero stress is at an annulus 0.66 of the diameter, with tensile stress outside and compressive stress within.

✦ ✦ ✦

General

H. J. FRENCH (34) discusses the phenomenon of delayed fractures. Hardened and slightly tempered steels which did not fail at 10 million repetitions, failed suddenly at 30 to 60 million repetitions. The steels were all nickel steels and delayed fractures were observed at hardnesses above the range 45 to 50 on the Rockwell C scale, but not at lower hardnesses. No mention of the same effect in straight-carbon steels was found in the literature.

✦ ✦ ✦

ANOTHER delayed-fracture effect is mentioned by A. Jünger (35) who found that flat bending specimens of hardened chrome-molybdenum steel, in which stress concentration was produced by a small hole, were breaking even after 75 million repetitions, whereas unbored specimens did not break after 5 million repetitions.

✦ ✦ ✦

2—Materials Investigated

THREE coils of straight-carbon tempered Swedish valve-spring wire were supplied by three different wire manufactures for the purpose of these tests. The wire was specially selected in regard to freedom from inclusions and for as nearly a perfect surface as could be obtained.

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THE stress-strain curves for static tensile and torsional tests of these wires are plotted in Figs. 1, 2 and 3, while the dimensions, chemical analyses, Rockwell hardnesses, and strengths are given in Table 1. The ultimate torsion strength was calculated from the formula

$$\frac{5.1 \times \text{maximum twisting moment}}{\text{diameter}^3}$$

✦ ✦ ✦

CARBON contents for the outer 0.001-in. thick layer were found to be 0.57, 0.59, and 0.59, respectively. Photomicrographs of the boundary material are discussed below.

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FATIGUE tests were made chiefly on the 0.225-in. and 0.187-in. diameter wires. Complete series of tests were not made on the 0.187-in. and 0.125-in. wires because of lack of time.

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POLISHED longitudinal sections and cross-sections of the 0.187-in. and 0.225-in. diameter wires were examined for inclusions. At 100 magnifications, inclusions were smaller in general than about 0.015 in., and no large inclusions were observed.

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TABLE 1—RESULTS OF TESTS ON THREE SPECIMENS OF TEMPERED SWEDISH WIRE

Diameter of wire, in.	0.125	0.187	0.225
Coil diameters are received, in.	28	36	36
Chemical analyses:			
Carbon	0.60	0.71	0.65
Manganese	0.35	0.60	0.59
Silicon	0.18	0.21	0.15
Phosphorous	0.023	0.020	0.020
Sulphur	0.026	0.022	0.021
Tensile strength, lb. per sq. in.:			
Ultimate	226,000	211,000	204,000
Yield point	203,000	190,000	181,000
Torsional strength, lb. per sq. in.:			
Ultimate	166,100	162,000	166,000
Yield point	139,400	125,000	120,500
Elongation in 8 in., per cent	4.2	5.7	6.2
Elongation in 2 in., per cent	6.9	9.9	10.5
Reduction of area, per cent	51.8	51.7	43.7
Hardness, Rockwell C	45.8	42.8	42.2
Stress-strain curve	Fig. 1	Fig. 2	Fig. 3.

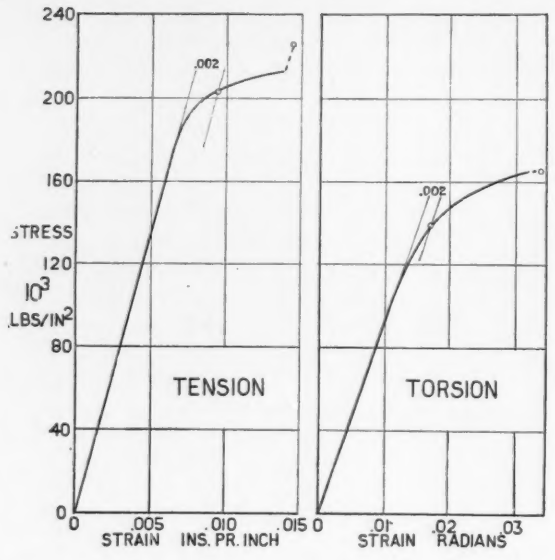

Fig. 1. Curves From Static Tests of 0.125-In. Diameter Tempered Swedish Wire.

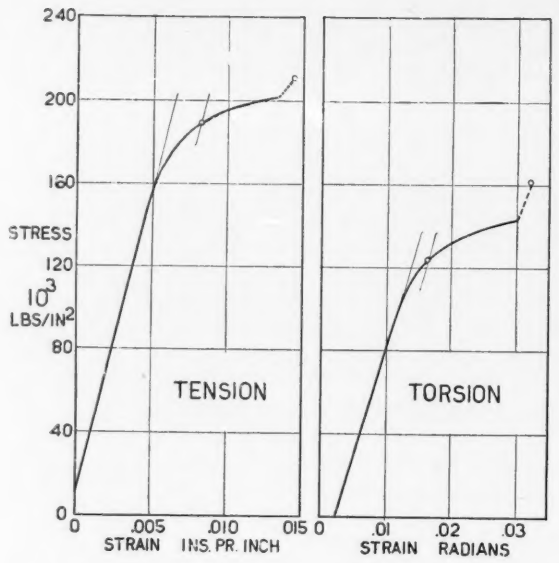

Fig. 2. Curves From Static Tests of 0.187-In. Diameter Tempered Swedish Wire.

THE structure at 1000 magnifications of a cross-section of the 0.187-in. wire is shown in Fig. 4, and of a longitudinal section of the 0.225-in. wire in Fig. 5.

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THE boundary of the 0.187-in. wire at 1000 magnifications is shown in Fig. 6 in which decarburization to a depth of about 0.0005 in. is shown.

✦ ✦ ✦

FIG. 7 shows decarburization at the boundary of the 0.225-in. wire, the oxide scale being in focus. Fig. 8 shows another portion of the boundary of the same wire, at which the distribution of ferrite is less disperse.

✦ ✦ ✦

THE photomicrographs show the extent of decarburization better than the carbon analyses previously given, as the latter gave the average carbon content for a layer twice as thick as the actual decarburized layer.

✦ ✦ ✦

3—Description of the Fatigue-Testing Machines

BENDING fatigue tests were made on a short-span rotating-beam-type machine, which was found to work satisfactorily for 0.225-in. and 0.187-in. diameter wires, but not for 0.125-in. wire. Clear lengths of specimens between 1½ in. and 2½ in. were used. Grips were cylindrically bored and fitted with an external cone and nut for clamping.

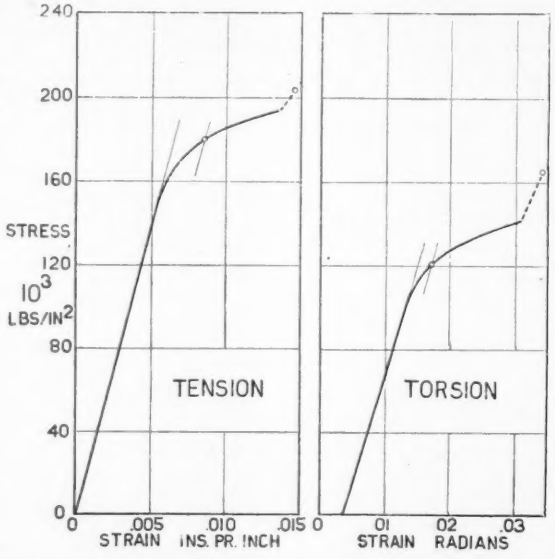

Fig. 3. Curves From Static Tests of 0.225-In. Diameter Tempered Swedish Wire.

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TORSION fatigue tests were conducted on three machines of the constant-strain type shown in Fig. 10. A ½-h. p. driving motor running at 1725 rpm was coupled to a shaft with a variable eccentric. A connecting rod gives an oscillating motion to one of the gripping chucks through a rocker arm of variable radius, the maximum angular motion being about 12 deg.

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THE second gripping chuck was originally clamped solidly on these machines, but in order to provide a means of determining the stress range at all times while the machine was in operation, a torsion-measuring member was inserted in series with the specimen under test. Two dial indicators measured the relative rotation of the two ends of this member at the extremities of the cycle. This device was calibrated statically under known torsion moments. Inertia effects in it were negligible, the calculated error with the proportions used being 0.1 per cent. Readings of the dials for zero torque were made at the beginning of a test with the specimen in place by unclamping the dead end of the torsionmeter and giving the assembly a slight oscillatory motion to eliminate friction.

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Fig. 4. Structure in a Cross-Section of the 0.187-In. Diameter Wire (X1000).

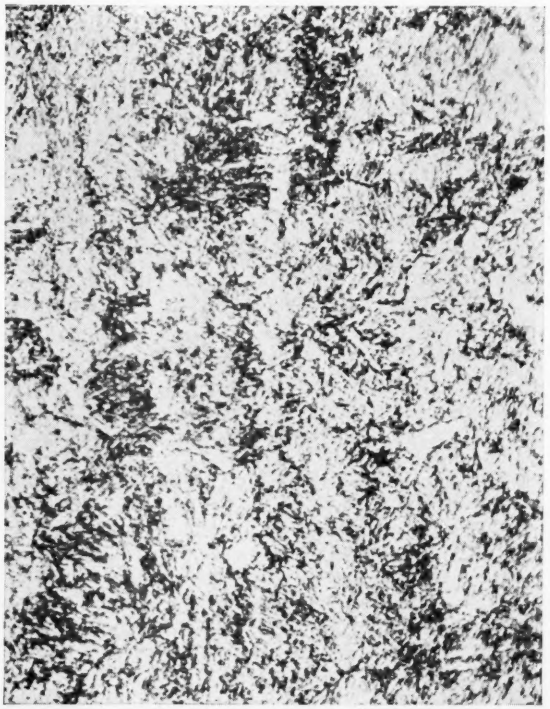

Fig. 5. Structure in a Longitudinal Section of the 0.225-In. Diameter Wire (X1000).

Fig. 6. Decarburization at the Surface of the 0.187-In. Diameter Wire (X1000).

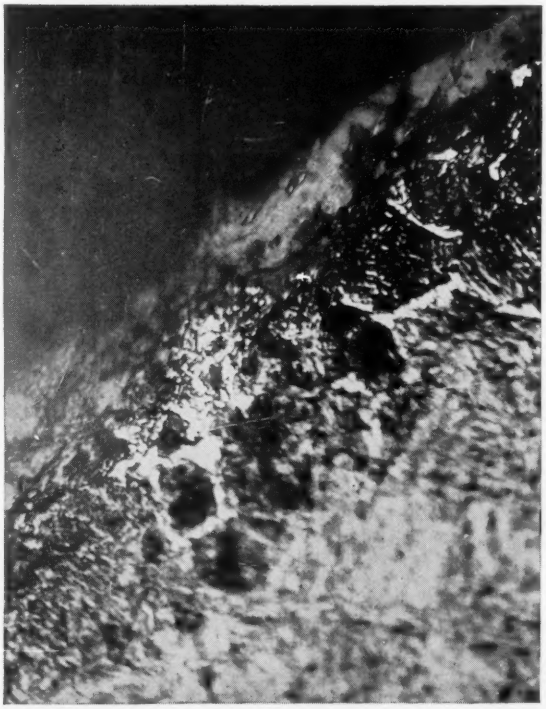

Fig. 7. Decarburization at the Surface of the 0.225-In. Diameter Wire, Showing Also the Oxide Scale (X1000).

A REVOLUTION counter was connected to the eccentric shaft. The motor was controlled through a 6-volt relay circuit, a current of 0.125 amp. passing through the specimen under test. A spring was provided to shift the oscillating grip a distance of about 0.0625 in., thus opening the circuit. Relays were adjusted so as to remain open after a momentary break in the circuit. This plan did not always stop the motor since contact was often maintained through the two parts of the fractured specimen. A phosphor-bronze leaf-spring contact in series with the specimen was therefore added at the end of the oscillating shaft which positively broke the circuit with a small endwise motion of the shaft and stopped the motor as desired.

✦ ✦ ✦

BALL-BEARINGS were used throughout, lubrication being maintained by oiling at the end of every one or two million cycles.

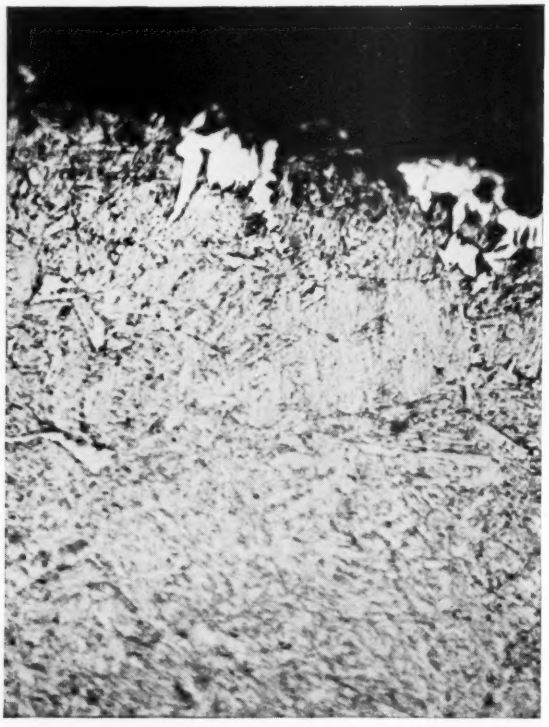

Fig. 8. Another Part of the Same Section of the 0.225-In. Diameter Wire Shown in Fig. 7 Illustrating a Different Type of Decarburization (X1000). ✦ ✦ ✦ ✦ ✦ ✦

Fig. 9. Seam About 0.001-In. Deep Found in Only One Section of the 0.225-in. Diameter Wire (X100). ✦ ✦ ✦ ✦

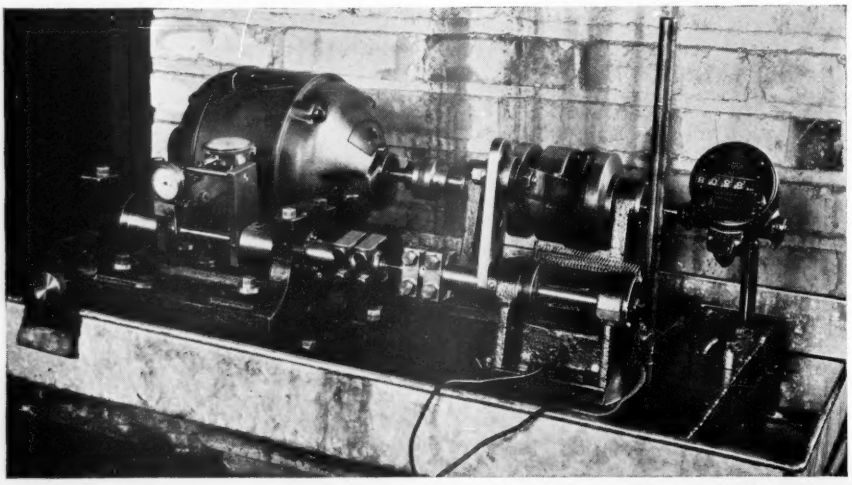

Fig. 10. Torsion Fatigue Machine Showing Motor, Eccentric Shaft, Oscillating Grip, Specimen in Place, Torsion Measuring Dials, and Cut-Out Switch at the Right End of the Oscillating Shaft. ✦ ✦

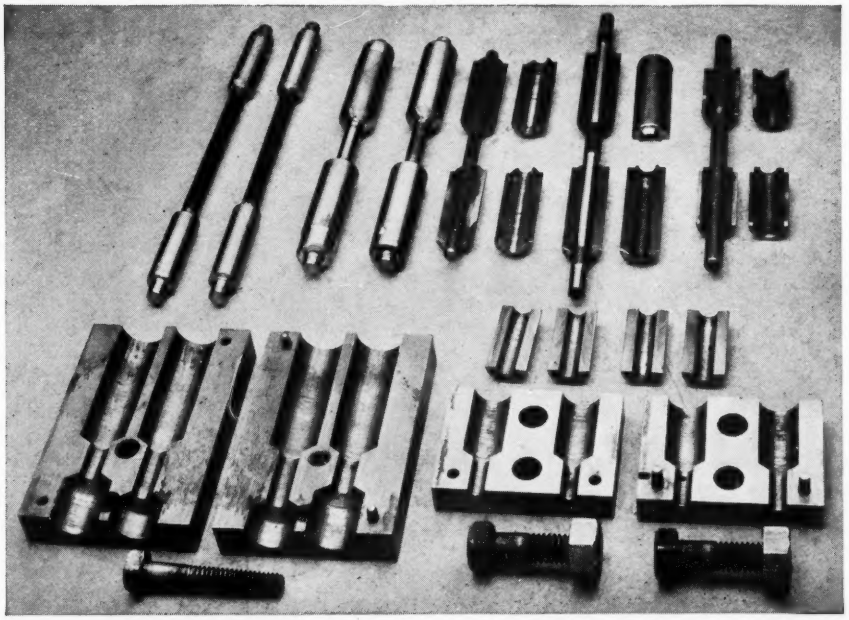

Fig. 11. Split Steel Molds; Bending and Torsion Specimens With Cast Type-Metal Ends; Different Types of Steel, Copper and Copper-Lead Bushings, and Specimens Prepared in Different Manners.

VIBRATION was reduced to a minimum by balancing the rotating eccentric parts and mounting the machines on thick sponge-rubber pads.

FOR tests at values of mean stress other than zero, a rotational adjustment was provided, which could be varied during operation.

THE split chucks were cylindrically bored to 0.5 in. diameter and each was clamped by means of four $\frac{5}{16}$-in. heat-treated bolts.

4—Development of Gripping Methods for Torsion Cast-End Method

AT the inception of this project no satisfactory methods of gripping were known for the torsion fatigue testing of tempered valve-spring wire in the as-received condition. Failure of straight wire specimens invariably occurred at the grips where the phenomena of stress concentration, microscopic rubbing, oxide formation, and corrosion were all present. The difficulties may be illustrated by Swan, Sutton & Douglas' torsion fatigue tests on Swedish wire (11). Of 25 specimens tested only two failed away from the grips, and another two ran unbroken for ten million stress cycles.

FOR cold-drawn wires, the difficulties had been overcome by F. C. Lea (2) by the use of cast type-metal ends. Adhesion was obtained by first tinning the ends of the wire which was then gripped in a split steel mold and poured with type metal. Molds and specimens of this type are indicated in Fig. 11. The temperature reached by the central portion of the wire in the process was not above 100 C, and when such high temperatures were reached they were only of momentary duration.

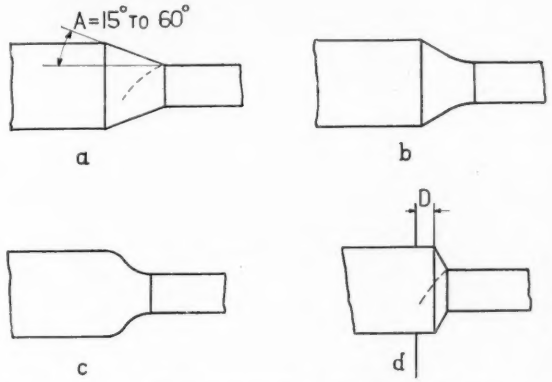

Fig. 12. Shape of the Ends of the Specimens Used in Torsion Fatigue Tests.

LEA'S method was taken as the starting point for the present work with tempered wire. The alloy used was described by Lea (2) as a white metal having a melting point as low as 107 C, and by Goodacre (3) as a type metal melting at 180 C. In the experiments reported in this paper, a matrix metal, a tin-lead solder, and a commercial monotype metal were tried first. The matrix metal contained 28.5 per cent lead, 14.5 per cent tin, 48 per cent bismuth, and 9 per cent antimony, and had a melting point of 105 C. The tin-lead solder had a melting point of approximately 180 C. The monotype metal analyzed 76 per cent lead, 8 per cent tin, and 16 per cent antimony, and had a melting point around 240 C.

THE matrix alloy and the tin solder did not adhere to the wire in torsion fatigue trials,

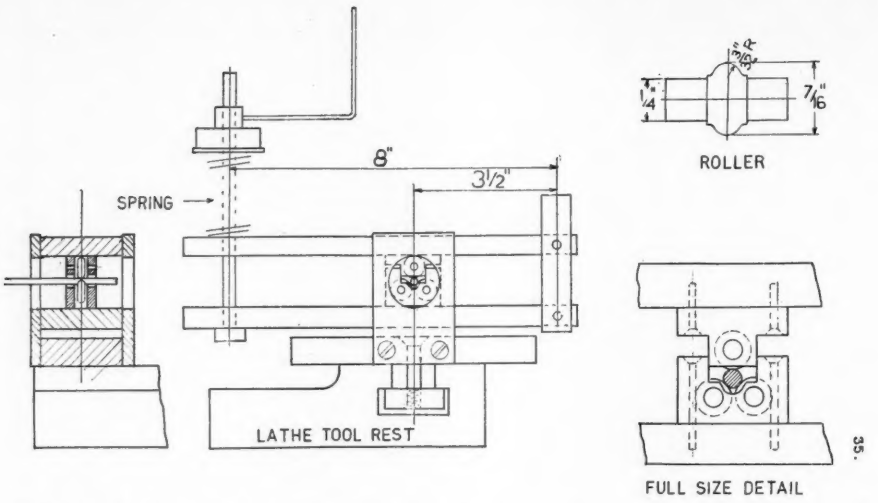

Fig. 13. Details of the Surface-Rolling Device Shown in Fig. 16.

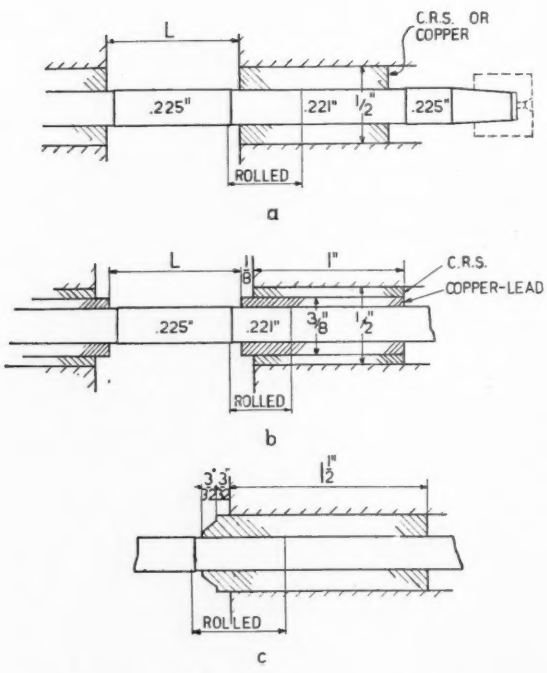

Fig. 15. Bushing Details for Grinding, Rolling, and Gripping Specimens.

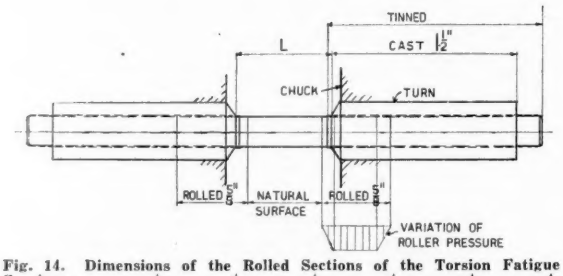

Fig. 14. Dimensions of the Rolled Sections of the Torsion Fatigue Specimens.

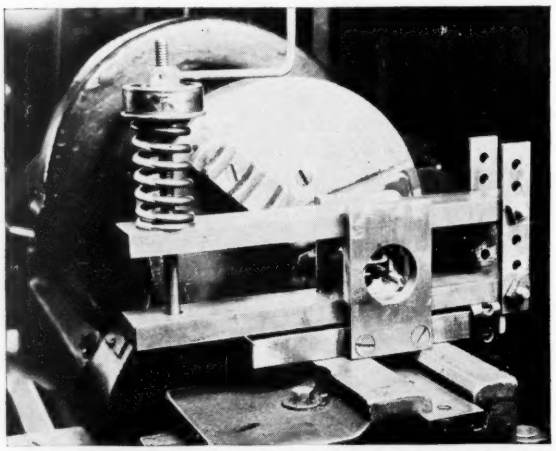

Fig. 16. Device for Rolling the Surface of the Wire. The Spring Was Calibrated to Produce Accurate Rolling Pressures.

whereas the monotype metal always adhered, even for torsional stresses in the wire as high as 140,000 lb. per sq. in. Monotype metal is relatively inexpensive, and as it seemed to meet the initial requirements it was used in subsequent tests.

✦ ✦ ✦

SPECIMENS of 0.125-in. wire were prepared with cast monotype ends and tested in torsion fatigue. In all cases in the early experiments failure occurred at the inner end of the molded type-metal shank. To reduce stress concentration effects the ends were variously shaped as shown in Figs. 12*a*, 12*b*, and 12*c* and were gripped at varying values of *D* shown in Fig. 12*d*, but fractures were always at the junction with the white metal thus indicating that stress concentration was probably not the chief cause of failure. For small angles *A* and for large values of *D* shown in Figs. 12*a* and 12*d*, re-

spectively, the white metal failed by cracking along a helix. In order to vary the hardness of the white metal, pouring temperatures were varied from 475 C to 300 C, and mold temperatures were reduced to as low as 5 C with no apparent effect on the position of wire fractures.

✦ ✦ ✦

A FEW specimens were clamped directly in a split-copper bushing with a 0.009-in. layer of detail paper between the wire and bushing. These failed at the grips.

✦ ✦ ✦

ONE specimen was clamped without paper in a split mild-steel bushing and failed at the grip.

✦ ✦ ✦

REMOVAL of the decarburized layer and polishing is known to greatly increase the fatigue strength of wire. When this was done and followed by tinning and casting on type-metal shanks, failure again, as with other methods, occurred at the grip.

✦ ✦ ✦

FIVE specimens of 0.187-in. wire were prepared with cast monotype ends for testing in the rotating-beam machine, in the belief that conditions here would not be so drastic as for torsion and that bending fatigue experiments could be started. Although the different shapes of the ends of the specimens shown in Figs. 12*a*, 12*b*, 12*c*, and 12*d* were tried, failure always occurred at the grips. One bending specimen was not tinned, but cast directly on the wire which had been fluxed in zinc chloride. It failed at the grip, indicating that tinning was not an essential cause of failure.

✦ ✦ ✦

THE presence of a yellowish white oxide at the junction of wire with cast shank suggested a similarity in the gripping problem to that of the failure of axles at a press fit, where stress concentration and corrosion fatigue due to the formation of oxides are present (8, 9, 10). In the experiments of Thum and Wunderlich remarkable increases of bending fatigue strength were obtained due to surface-rolling. This process was next tried and since it met with success it will be described in detail.

✦ ✦ ✦

Surface-Rolling of Wire Specimens

THE apparatus detailed in Fig. 13 and shown in Fig. 16 was assembled and used to roll the surface of wire specimens at the points where failure had previously been found to occur. The rollers were made of 7/16-in. diameter hardened steel with the face crowned to 3/32-in. radius. Roller dimensions were taken from the dissertation of O. J. Horger (9). A load of approximately 100 lb. was used at the spring, giving roller loads of about 230 lb. each. The approximately straight wire specimens were gripped in a lathe chuck and rotated at various speeds. The 0.225-in. wire was rotated at 25 rpm and the 0.187-in. wire at 35 rpm, giving a surface speed of 1.5 rpm. A feed of 0.0055 in. per revolution was used.

✦ ✦ ✦

WITH the roller dimensions and loading as given, the maximum shear stress in a perfectly elastic solid calculated by the Herz theory for contact stresses was in the neighborhood of 500,000 lb. per sq. in. The yield point in shear of the tempered wire is from 120,000 to 140,000 lb. per sq. in. Consequently, this extremely high stress is not reached but plastic flow takes place to a depth depending upon the roller pressure. The slow rolling speed allows time for plastic flow to occur. As a result of rolling, the surface material is work-hardened, is made more dense, and is left with heavy compressive residual stresses, all of which probably contribute to its increased fatigue strength.

✦ ✦ ✦

TWO portions of the wire specimen, each about 5/8 in. long, were rolled as shown in Fig. 14. The roller pressure was increased linearly from zero to a maximum in a length of 1/16 in. to 1/8 in. and similarly reduced to zero at the other end of the rolled portion. The tinning was not permitted to touch the natural surface of the wire in the center portion because of possible penetration and weakening (5). The cast end was kept clear of the end of tinned portion so that perfect adhesion was obtained. The beveled ends of the wire specimen were centred in female lathe centers for turning the type-metal ends to fit the chucks of the torsion machine. It was obviously not necessary for the wire to be straight with this method of gripping.

✦ ✦ ✦

BEFORE tinning, the ends of the wire were rubbed lightly with emery cloth to remove scale, and fluxed in zinc-chloride solution. They were tinned by dipping into molten 50/50 lead-tin solder at 325 C. The momentary temperature reached at a point in the wire just clear of the tinning did not in general exceed 75 C. This was measured by inserting a thermocouple in small holes drilled in pieces of 1/8-in. and 1/4-in. drill rod, and tinning these as for the wire specimens.

✦ ✦ ✦

THE monotype metal was poured at 325 C and the molds were usually at or slightly below room temperature. The split molds weighed 0.60 and 1.25 lb. for the 0.187-in. and 0.225-in. wires, respectively. The metal cooled quickly and wire temperatures as measured by thermocouples did not exceed 75 C.

✦ ✦ ✦

THE combination of cast ends with surface rolling of the wire was successful for alternating torsion fatigue tests on as-received wire and on wire with the surface ground. Practically every specimen failed away from the gripping points. The method was not successful for shot-blasted wire, since the surface material of this wire is strengthened greatly by work-hardening. The method was successful for bending fatigue tests in a short-span rotating-beam machine on wire in the as-received, ground, shot-blasted, and shot-blasted-and-blued conditions.

✦ ✦ ✦

TO obtain torsion fatigue results for shot-blasted wire, a surface layer of approximately 0.0015 in. was removed from the two end portions of the specimens after

which they were polished and rolled. Since the wire specimens were not perfectly straight it was necessary to rotate them in a lathe and clean them with emery cloth. All scratches had to be removed to eliminate the danger of the specimen breaking at the scratches. The few specimens prepared in this way did not fracture as desired, probably due to scratches from the emery, but the double strengthening due to removal of decarburized layer and to surface rolling should more than counterbalance the strengthening in the center portion of specimen due to shot-blasting. Further work with this method should yield results.

✦ ✦ ✦

WHEN the cast-end type of specimen was tested in a zero-to-maximum torsion-stress cycle, there was a continuous angular creep in the type-metal ends. The effect of this creep was to shift the stress range to a position with a lower mean stress value so that it was necessary to adjust the machines at frequent intervals in order to maintain the intended stress cycle. The cast-end method was consequently abandoned for zero-to-maximum stress cycles, although it is probable that an automatic method of maintaining the proper stress cycle can be worked out. This may be a desirable development as the cast-end method has the great advantage of reducing stress concentration to a minimum.

✦ ✦ ✦

Split-Bushing Methods

FOR tests in a zero-to-maximum torsion-stress cycle, split bushings were used to grip the wire. In conjunction with the bushings surface rolling was always used to strengthen the wire in the critical region. Bushing materials experimented with were ordinary cold-rolled steel, hard-drawn copper, and a copper-lead alloy with about 25 per cent lead. Steel was used because of its high coefficient of friction, requiring lower gripping pressures, while copper-lead was used because of its successful application in the pulsating tensile tests of Shelton and Swanger (13). The friction coefficient of brass was too low for satisfactory gripping. In some cases the ends of bushings were faced square with no attempt at relieving stress concentration, while in other cases they were beveled in an attempt to reduce the pressure peak occurring at the ends. When set in the machine they were chucked sometimes flush at the ends, and sometimes protruding a short distance, which was believed to reduce the pressure peak due to gripping. In some cases a thickness of paper was used between the wire surface and the bushing bore. Rolling and subsequent gripping of the wire were done either directly on the natural surface or on a portion which was polished after being reduced about 0.004 in. in diameter to remove the decarburized layer.

✦ ✦ ✦

THE wire diameter was reduced either by grinding between centers which could only be done on samples specially selected for straightness, or more practically by hand in a lathe using strips of successively finer emery cloth. Bushings were drilled solid with a twist drill and sometimes finish-bored by a gun reamer with which it was attempted to bore them 0.0005 in. smaller than the neat-wire size. They were split into halves by a 1/64-in. milling cutter, and in one case each half was slotted to provide greater flexibility in clamping around the surface of the wire.

✦ ✦ ✦

FIVE specimens of 0.225 in. wire in the as-received condition were selected for straightness and ground between centers to 0.221 in. diameter using the tapered-end fittings shown in Fig. 15*a*. They were rolled and gripped by the methods of either Fig. 15*a* or Fig. 15*b*. Specimens Nos. 350 and 351, shown in Fig. 25, were gripped in the copper-lead bushing detailed in Fig. 15*b*. Both of these specimens fractured in the center as shown in Fig. 25. However, the fracture of specimen No. 350 was at a surface flaw as is evidenced from the stress-repetition or S-N curve in Fig. 18. Specimen No. 352 was gripped in a copper bushing 1 in. long, as shown in Fig. 15*a*, and was run 10.1 million cycles of 0 to 97,000 lb. per sq. in. stress without breaking. Specimen No. 353 shown in Fig. 25 was gripped in a cold-rolled steel bushing 1 in. long and broke in the center portion. Specimen No. 354 similarly gripped in a steel bushing was removed unbroken after 4.4 million cycles. Very little galling of the wire surface was evidenced. Copper-lead bushings could not be used more than once because of plastic deformation. The method may be considered successful but somewhat elaborate.

✦ ✦ ✦

IN an effort to simplify the procedure, the reduction in diameter of the gripped portions of specimens was omitted. The natural surface of the wire, or 0.187 in. diameter in this case, was rolled as required, the scale was removed with fine emery paper, and the wire was gripped in split copper bushings. Although the wire had been straightened by hand bending none of the specimens were actually straight so that gripping in the torsion machine would introduce small static bending stresses which were neglected. Specimens Nos. 201 to 207 were prepared in the manner described and gripped in copper bushings having an end detail as shown in Fig. 15*c*. Specimens Nos. 201, 205, and 206 fractured clear of the grips while specimens Nos, 202, 203, and 204 broke at the grips. Specimen No. 207 ran 10.1 million cycles at 0 to 105,000 lb. per sq. in. stress. There was noticeable galling and probably penetration of the copper into the steel wire at points near the inner ends of the bushings where the pressure was greatest. Fatigue cracks started at such points. It was believed that the decarburized surface was particularly susceptible to this welding or seizing action and the next group of specimens Nos. 208 to 210, were prepared with the gripped portions reduced in a lathe to 0.183 in. by emery cloth previous to the surface-rolling operation. Fig. 15*c* indicates the tapered end of bushing and projection from the chuck

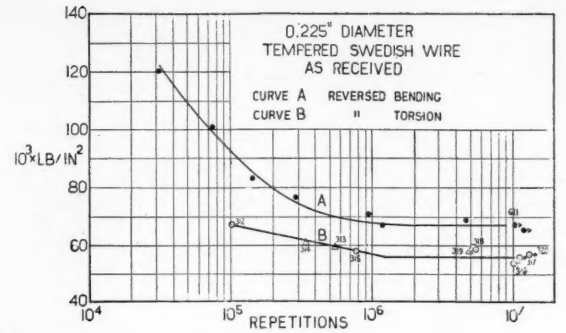

Fig. 17.

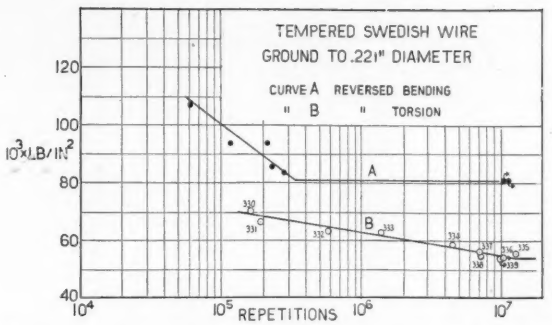

Fig. 19.

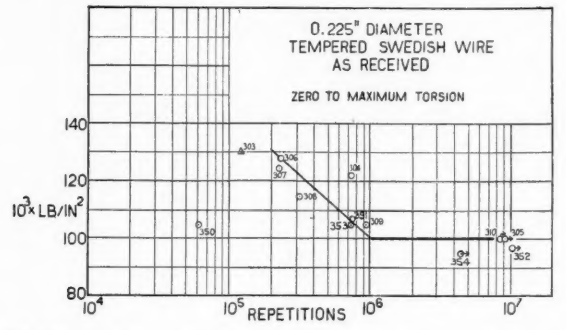

Fig. 18.

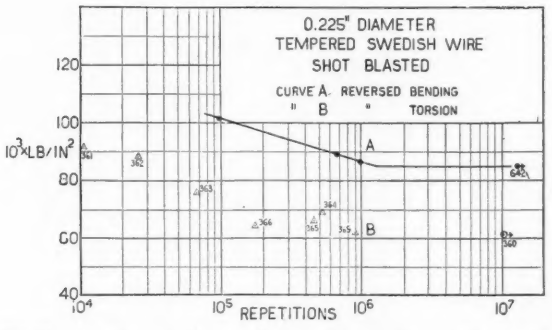

Fig. 20.

as used for all three specimens. Specimen No. 208 was gripped in a steel bushing and broke at the grip. Specimens Nos. 209 and 210 were gripped in split copper bushings but were first wrapped with a 0.003-in. layer of a high-grade linen bond paper. The bushings had been bored to 0.185 in. diameter and therefore had to be forced onto the paper-covered specimen. Both specimens broke clear of the bushings. The paper was somewhat disintegrated at the inner ends of bushings, as is usual, due to small relative motion. There was also some fusing of copper to steel.

✦ ✦ ✦

IT is believed that with better distribution of gripping pressure most of the failures at the grips in these experiments might have been avoided. A good bond-paper filler will compensate for irregularities in the surface of the bushing bore, but it is also necessary that the gripping pressure be distributed radially around the wire surface rather than along two lines which are diametrically opposite to one another. To obtain this distribution, an undersized bushing bore was tried as mentioned, and in some cases a paper filler was placed between the outside of the bushing and the bored hole of the torsion-machine chucks. This had the effect of forcing-in the opposite edges of the bushing halves and thus improving the distribution of pressure.

✦ ✦ ✦

WELDING of the bushing material to the wire surface had troublesome consequences in the tests. Apart from providing points of weakness, it reduced the effective length of specimen between grips and thus, since the torsion machines are constant-strain machines, increased the range of stress applied to the specimen. The action was progressive and called for frequent strain adjustments to keep the stress range within reasonable limits. This effect was observed on the 0.187-in. wire gripped on the natural surface and when reduced to 0.183 in. by emery cloth and paper. It was also observed on the 0.225-in. wire ground between centers to a 0.221-in. diameter gripping seat when gripped in copper-lead bushings (specimen No. 351), but was not observed when gripped in steel or copper bushings (specimens Nos. 354 and 352). These latter results do not agree with Shelton and Swanger's (13) conclusion that copper-lead causes less galling of the surface than copper, and it may be, as mentioned previously, that the distribution of gripping pressure was the determining factor.

✦ ✦ ✦

THE stress range did not remain constant throughout the endurance test of any one specimen, although in some instances the variation was very small. In contrast with the phenomenon mentioned previously, some specimens gripped in split bushings showed a gradual reduction in stress range, probably due to a loosening of the wire at the inner ends of the bushings. The specimens with cast type-metal ends always showed a reduction in range which seemed to be due to relaxation under the gripping pressure, and consequent loosening in the chuck. This was corrected easily by tightening the gripping bolts. The effect was

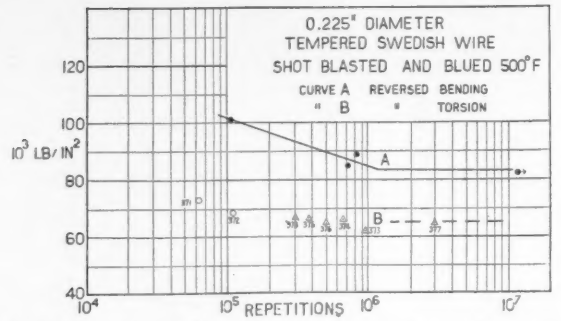

Fig. 21.

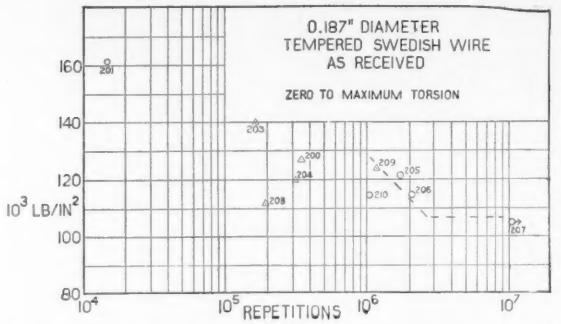

Fig. 23.

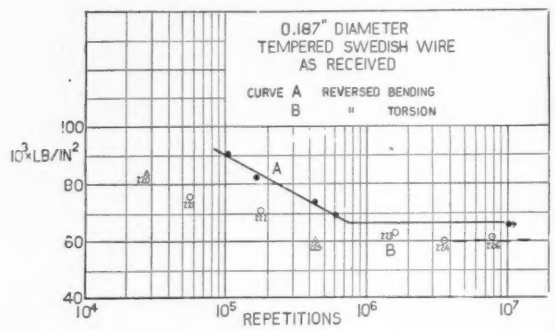

Fig. 22.

TABLE 2—VARIATION IN STRESS RANGE IN SEVERAL OF THE TESTS

Specimen no.	Type grip	Variation in range
207	Copper bushing	Increase 6% in 2 million cycles
208	Steel bushing	Increase 3 to 5% in 0.2 million cycles
224	Monotype metal	± 7% in 3.6 million cycles
226	Monotype metal	Decrease 1.5% in 2.5 million cycles
364	Monotype metal	Decrease 8% in 0.5 million cycles
354	Steel bushing	Decrease 1% in 4.5 million cycles
351	Copper-lead metal	Increase 7.5% in 0.7 million cycles
352	Copper bushing	Decrease 4.5% in 2.2 million cycles
338	Copper bushing	Decrease 1.0% every 2.5 million cycles

greatest at high stress ranges when specimens heated up considerably, but was quite small in tests near the fatigue limit. Regular attention and readjustment was thus necessary in all torsion tests to maintain stress ranges within satisfactory limits. The observed variations in stress range for some individual specimens are given in Table 2.

✦ ✦ ✦

5—Test Procedure

THE wire surface was examined by etching in a solution of equal amounts of concentrated hydrochloric acid and water maintained at 80 C. The wire was reduced in diameter in steps of about 0.0005 in. and examined at each stage until a reduction of about 0.004 in. had been made. The surface of all three sizes was exceptionally homogeneous and free from defects. With much deeper etching longitudinal streaks appeared which were probably not related to the original surface.

✦ ✦ ✦

A SEAM about 0.001 in. deep, found in a photomicrograph of the 0.225-in. wire, shown in Fig. 9, could not be located in other sections and therefore probably did not extend a great distance in the wire.

✦ ✦ ✦

FRACTURES were examined directly and at about 10 magnifications. In general, inclusions, if present at the point of origin of the fatigue crack, were too small to be seen, but their presence was often indicated by a slight distortion of the fractured surface at this region, as it is known that the value of stress and its direction in the region of a cavity are largely determined by the shape of the cavity. Some individual specimens which did not show up well in the fatigue tests showed failure to have begun at an inclusion or seam as, for example, specimens Nos. 350 and 221, shown in Figs. 25 and 27, respectively. A few cross-sections of failed specimens were polished and examined at 100 magnifications for cracks without success.

✦ ✦ ✦

THE clear length between grips of torsion specimens was determined by the maximum angular travel of the oscillating chuck, and the stress range desired for the individual specimen. Values of length L used in the tests were approximately as follows:

Wire diameter, in.	L
0.125	$\frac{5}{8} \pm \frac{1}{8}$
0.187	$\frac{3}{4} \pm \frac{1}{8}$
0.225	$\frac{7}{8} \pm \frac{1}{4}$

✦ ✦ ✦

SPECIMENS were cut to a length of about 4½ in. and prepared with either cast ends or split bushings as previously described.

✦ ✦ ✦

IN the early tests on 0.225 in. wire, it was used just as it came from the coil, having a slight natural curvature. In all later tests, for convenience, the wire was hand-straightened by being bent in opposition to this natural curvature. Residual stresses were no doubt present in both cases.

✦ ✦ ✦

CARE was taken not to scratch the wire in preparing specimens, as it was found that scratches were often, though not always, the points at which the deciding fatigue crack started.

✦ ✦ ✦

SPECIMENS were mounted in the testing machine which was started at approximately the desired stress range. By adjustment of the angular travel of the oscil-

lating grip the desired stress range would be obtained in a few thousand stress cycles. Adjustments were made as required to maintain a fairly constant range.

✦ ✦ ✦

IN general, a point on the fatigue diagrams of Figs. 17 to 23 represent a stress cycle which did not vary more than ±5 per cent. Error in reading torque was about 0.5 per cent, and the error in initial calibration is estimated at 0.5 per cent.

✦ ✦ ✦

TORSION stresses were calculated by the formula

$$\text{Maximum shear stress} = \frac{5.1 \times (\text{maximum twisting moment})}{\text{Diameter}^3}$$

✦ ✦ ✦

BENDING stresses were calculated by the formula

$$\text{Maximum bending stress} = \frac{10.2 \times (\text{maximum bending moment})}{\text{Diameter}^3}$$

the calculated segmented area of the portion removed the longitudinal stress in the surface material can be found. A change of curvature in one direction indicates a tension stress, while a change in the opposite direction indicates a compression stress.

✦ ✦ ✦

MEASUREMENTS were made on straight pieces of wire in different conditions and on half-coils of wire specially prepared for the measurement of coiling stresses. Fig. 30 shows the device for measuring the coiling stresses with a half coil clamped in position and an ordinary micrometer arranged to measure deflections. Contact was determined by the use of ear phones and a battery circuit.

✦ ✦ ✦

WHERE residual stress values are given, the possible error might easily be ±50 per cent although the figures given are averages of 2 to 4 separate determinations which usually agreed within ±25 per cent. Measurements of coiling stresses were made in a limited time and only relative values of stresses are available.

✦ ✦ ✦

6—Results of Tests

THE results of tests on 0.225-in. and 0.187-in. wire are plotted as stress against the logarithm of the number of repetitions to failures on the S-N diagrams of Figs. 17 to 23. Fractures which occurred away from the ends are indicated by circles while specimens which did not fracture are indicated by a circle and an arrow. In some cases, since they provide useful information, fractures which occurred at or near the grips are included, and are indicated by triangles.

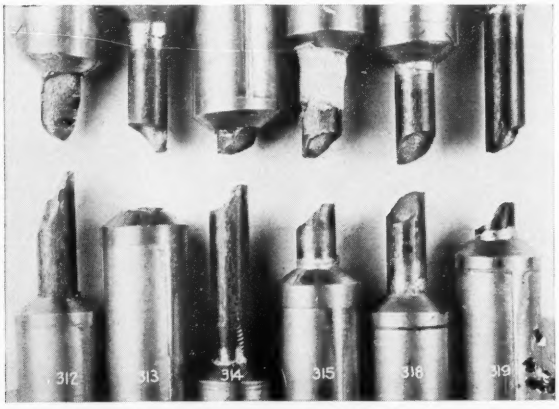

Fig. 24. Typical Fatigue Fractures of 0.225-In. Wire Tested in Alternating Torsion. Wire Used in As-Received Condition. ✦ ✦

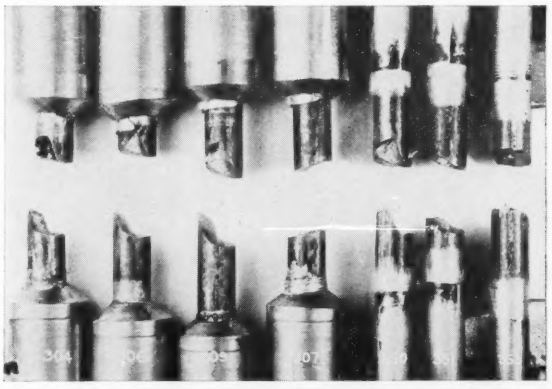

Fig. 25. Typical Fatigue Fractures of 0.225-In. Wire Tested in Zero-to-Maximum Torsion. Wire Used in As-Received Condition. ✦

BECAUSE of its possible effect on the relative strength in torsion and bending fatigue, the presence of residual stress in the wire was verified experimentally. The method neglects any circumferential stress which may be present and, therefore, at best is only approximate. A flat surface about $\frac{1}{32}$ in. wide was ground on one side of a length of wire and the change in curvature of the wire noted. From the change in curvature and

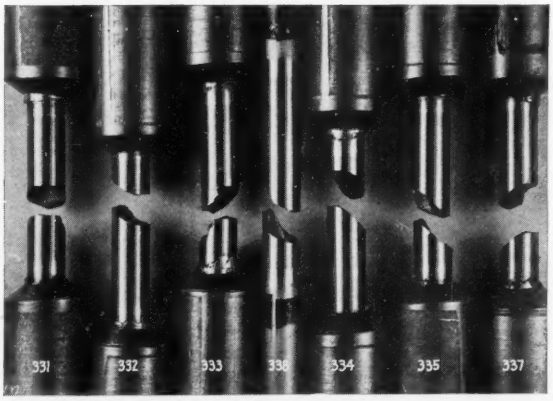

Fig. 26. Typical Fatigue Fractures of 0.221-In. Centerless-Ground Wire Tested in Alternating Torsion. ✦ ✦ ✦ ✦

Results of Tests on 0.125-In. Wire as Received

A COMPLETE series of tests was not made on 0.125-in. wire as received, but the results of tests on two specimens give some idea of the fatigue strength in a zero-to-maximum torsion stress cycle. One specimen without failure withstood 15 million repetitions of a stress cycle which at the beginning of the test was from zero to 125,000 lb. per sq. in., at 10 million

zero to 107,000 lb. per sq. in., and at 15 million zero to 106,000 lb. per sq. in.

✦ ✦ ✦

ANOTHER specimen broke after 5.7 million repetitions of a stress cycle which at the beginning of test was from zero to 124,000 lb. per sq. in., at 0.26 million cycles it was from zero to 116,000 lb. per sq. in., and at the end of the test it was from zero to 113,000 lb. per sq. in.

✦ ✦ ✦

FROM these two tests the zero-to-maximum torsion endurance limit for 0.125 in. wire as received may be estimated at something over 110,000 lb. per sq. in.

✦ ✦ ✦

sq. in. Bending fractures shown in Fig. 29*a* were smooth and showed clean material. Torsion fractures also were all in homogeneous material, the crack starting at about 45 deg. to the axis forming two roughly symmetrical fractured surfaces as shown in Fig. 24. Reversed torsion endurance limit is 0.84 times the reversed bending endurance limit.

✦ ✦ ✦

ZERO-to-maximum torsion tests showed an endurance limit of 100,000 lb. per sq. in. as observed from Fig. 18. Fractures of this specimen, shown in Fig. 25 were unsymmetrical and of a different type. The fatigue crack started at about 45 deg and curved around the specimen in circumferential and longitudinal directions. Specimen No. 350 gave a point well off the curve and the position of the surface responsible for failure can be seen in Fig. 25. Fractures otherwise showed clean material.

✦ ✦ ✦

Tests of 0.225-In. Wire Reduced To 0.221-In. in a Centerless Grinder

THIS series of tests was run to determine the effect of a surface-grinding treatment which might be commercially practicable. A single pass across a 60-grit wheel was used. The surface though smooth in appearance was considerably coarser than a surface polished with No. 1 emery paper. It was found that due to slight curvature of the wire before grinding, a variable thickness of layer was removed. Only specimens which had "cleaned up" all over were tested.

✦ ✦ ✦

FATIGUE curves for this test are shown in Fig. 19. The bending endurance limit is 81,000 lb. per sq. in., an increase of 21 per cent over the value for wire as received, in spite of the fact that grinding marks are circumferential. Bending fractures of the specimens used in this test, shown in Fig. 29*b*, are seen to be slightly stepped and ragged, and are not as clean cut as for the as-received wire.

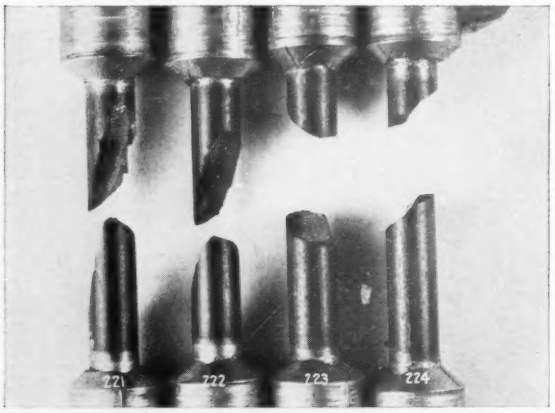

Fig. 27. Typical Fatigue Fractures of 0.187-In. Wire Tested in Alternating Torsion. Wire Used in As-Received Condition. ✦ ✦

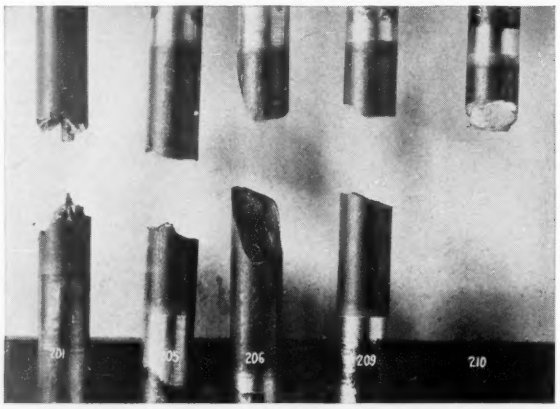

Fig. 28. Fatigue Fractures of 0.187-In. Wire Tested in Zero-to-Maximum Torsion. Wire Used in As-Received Condition. ✦ ✦

Result of Test of 0.225-in. Wire as Received

THE bending fatigue results show little scatter, as seen from the curves in Fig. 17, and give a smooth curve, with the endurance limit at 67,000 lb. per sq. in., which is 33 per cent of the ultimate strength of 204,000 lb. per sq. in. Reversed torsion tests show an endurance limit of 56,000 lb. per sq. in., which is 34 per cent of the ultimate torsional strength of 166,000 lb. per

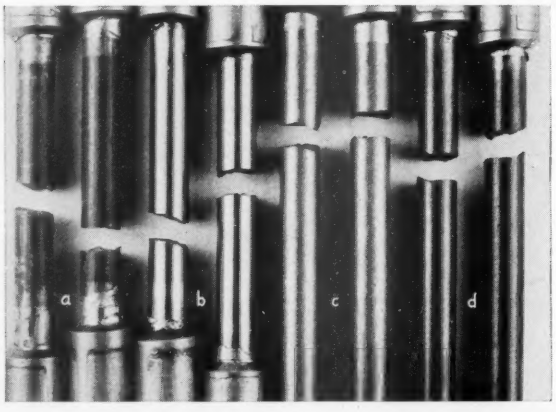

Fig. 29. Typical Bending Fatigue Fractures of 0.225-In. Wire. (a) As-Received Condition; (b) Ground to 0.221-In. Diameter; (c) Shot-Blasted Condition; (d) Shot-Blasted and Blued Condition. ✦

THE endurance limit is reversed torsion from the curve in Fig. 19 is 54,000 lb. per sq. in., which is 4 per cent lower than the value for as-received wire and 0.67 times the reversed bending endurance limit of ground wire. Fractures occur at 4½, 6, and 13 million cycles, and the curve does not become horizontal until about 10 million cycles are reached.

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THE "delayed fractures" of French (34) and Jünger (35) are suggested by these results. French found that fractures occurred after 10 million cycles in nickel steels harder than about 45-50 Rockwell *C*, but not in steels with lower Rockwell values. Removal of the soft outer surface may leave a surface which is in the hardness range where delayed fractures occur, and the usual test to 10 million cycles is not sufficient. Also the grinding marks might provide stress concentrations and cause delayed fractures such as Jünger observed. These effects are not present in the bending fatigue curve, however.

✦ ✦ ✦

AN examination of the fractured torsion specimens showed that a cross-section of specimen No. 330 revealed no cracks or seams. The fractured surface was stepped and a crack extended at about 45 deg. into the metal, suggesting the presence of an inclusion. Specimens Nos. 332, 333, 334, 335, and 337, Fig. 26, showed slight irregularities on the fractured surface at the region of crack formation which might have been flaws, whose effect was accentuated in some manner by the grinding.

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Results of Tests on 0.225-In. Shot-Blasted Wire

WIRE in the as-received condition was shot-blasted in a standard revolving drum for 25 min. with air at a pressure between 70-75 lb. per sq. in.

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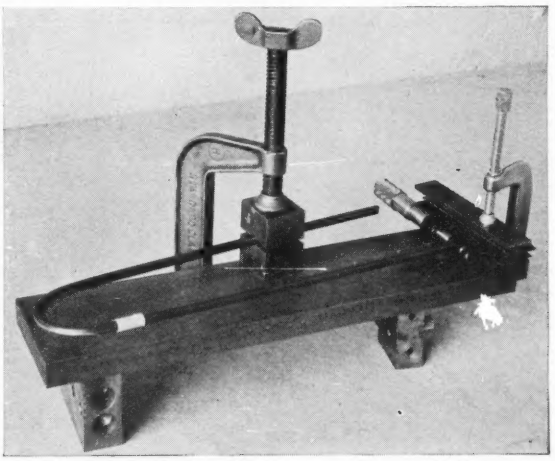

Fig. 30. Device for Measuring Coiling Stresses in a Half-Coil. ✦

(A flat spot is ground on the inner surface of the coil and the deflection of the arm is measured by a micrometer. Earphones and a battery circuit are used to record contact at the micrometer.) ✦

THE reversed bending endurance limit as shown by the curve in Fig. 20 was 85,000 lb. per sq. in., which is 27 per cent higher than for wire as received. Bending fractures of the specimens are shown in Fig. 29*c*.

✦ ✦ ✦

ALL torsion fractures occurred at or near the grips and these are shown on the diagram in Fig. 20 by triangles. One specimen ran 10 million cycles at 61,500 lb. per sq. in. without fracture. The true fatigue curve will lie above the triangular points in Fig. 20 representing fracture at the grips so that the endurance limit is estimated to be an unknown amount above 61,500 lb. per sq. in.

✦ ✦ ✦

Results of Tests on 0.225-In. Shot-Blasted-and-Blued Wire

AFTER shot-blasting the specimens were blued at 500 F for 30 minutes in a Homo furnace and cooled in the furnace.

✦ ✦ ✦

THE bending-endurance limit shown by the curve in Fig. 21 is 83,000 lb. per sq. in., which is about 24 per cent greater than for wire as received. Fractures were slightly irregular but clean, and

TABLE 3—BENDING AND TORSION ENDURANCE VALUES FOR TEMPERED SWEDISH VALVE-SPRING WIRE[b]

Diameter, in.	0.125[b]	0.225[b]	0.221[c]	0.225[d]	0.225[e]	0.187[a]
Reversed bending endurance limit, lb. per sq. in.	.....	67,000	81,000	85,000	83,000	67,000
Percent of ultimate tensile strength	.....	32.8	.....	.....	.....	31.8
Reversed torsional endurance limit, lb. per sq. in.	.....	56,000	54,000	61,500+	65,000+	60,000
Percent of ultimate torsional strength	.....	33.7	.....	.....	.....	37.0
Ratio of reversed torsional stress to reversed bending stress	.....	0.84	0.67	0.72+	0.78+	0.90
Zero-to-max. torsional stress endurance limit, lb. per sq. in.	111,000+	100,000	.....	.....	.....	107,000
Ratio of zero-to-max. torsional endurance limit to reversed bending stress	.....	1.49	.....	.....	.....	1.60
Ultimate tensile strength, lb. per sq. in.	226,000	204,000	.....	.....	.....	211,000
Ultimate torsional strength, lb. per sq. in.	166,100	166,000	.....	.....	.....	162,000

[a] Based upon 10 million stress reversals.
[b] Wire tested in as-received condition.
[c] Wire ground to size from 0.225 in. diameter with No. 60 grit.
[d] Wire shot-blasted before testing.
[e] Wire shot-blasted and blued before testing.

are shown by the specimens in Fig. 29d.

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ONLY two reversed-torsion specimens fractured clear of the grips although some of the other fractures started clear of the grips and extended to them. None of the specimens ran 10 million cycles without fracture, but the endurance limit is probably above 65,000 lb. per sq. in.

✦ ✦ ✦

Results of Tests on 0.187-In. Wire as Received

THE bending fatigue limit for 0.187-in. wire as-received is shown on the curve in Fig. 22 to be 67,000 lb. per sq. in., which is about 32 per cent of the ultimate strength of 211,000 lb. per sq. in.

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SEVEN points are shown for the reversed - torsion endurance curve, two of which represent failure at the grips. No specimen ran through 10 million cycles without failure, up to the time of making the diagram, but the endurance limit is very probably at 60,000 lb. per sq. in., which is 0.90 times the reversed bending endurance limit, and 37 per cent of the ultimate torsional strength.

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SOME torsion fractures of the 0.187-in. specimens are shown in Fig. 27. Specimen No. 221 failed at a longitudinal surface flaw or inclusion about 0.04 in. long. Two diagonal cracks are seen extending from the points of stress concentration at each end of the flaw.

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THE curve for zero-to-maximum torsion tests on 0.187 in. wire is shown in Fig. 23. One specimen was unbroken after 10 million reversals at 105,000 lb. per sq. in. A greater number of significant points was not obtained because of difficulties encountered with seizing of the copper-bushing to the wire thereby increasing the stress range in an erratic manner. The endurance limit is estimated at 107,000 lb. per sq. in. Specimen No. 210 failed clear of the grips but a radial crack about 0.03 in. long could be seen on the fractured surface, which explains the position on the diagram. Specimen No. 201 was accidentally run at a very high stress. Fracture started at many points forming a ragged cone and a conical hollow. There was considerable slipping in the copper bushing at this high stress.

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A TABULATION of all fatigue results is given in Table 3.

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Residual Stresses

THE following results of residual stress measurement are included for their suggestive value. Errors of ±50 per cent or more may be present.

(*a*) *As Received.* One piece of 0.187-in. wire and one piece of 0.225-in. wire, just as they came off the 36-in. diameter coils with a slight permanent set or curvature, were used to determine the residual stress along four edges spaced 90 deg. around the wire. No check measurements were made in this case. The results of this test are given in Table 4.

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THE results in Table 4 show very well that even coiling to 36 in. diameter leaves large tensile stresses at the inside of the coil and corresponding compression stresses at the outside. The averages of the values measured along the two flat sides are approximately 25,000 lb. per sq. in. in both cases, which is probably not sufficient to materially affect fatigue strength (29).

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(*b*) *Ground 0.221-In. Diameter Wire.* Measurements on three samples of this wire were erratic and gave compressive longitudinal stresses from 0 to 8000 lb. per sq. in. The fact that an uneven thickness of layer was removed will explain the variation in stress measurements.

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(*c*) *Shot-Blasted 0.225-In. Diameter Wire.* Measurements on three samples gave values of longitudinal compressive stress which were within ± 12 per cent of 165,000 lb. per sq. in.

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(*d*) *Shot-Blasted and Blued 0.225-in. Diameter Wire.* Three measurements gave values of longitudinal compression within ± 14 per cent of 27,600 lb. sq. in. The bluing treatment reduced shot-blasting stresses to one-sixth their value.

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(*e*) *Measurements on Fatigue Specimens.* Bending specimen No. 611, made of 0.225-in. diameter as-received wire, after 10 million reversals at 67,000 lb. per sq. in., showed an average value of longitudinal tension stress, for four sides of the wire of 73,000 lb. per sq. in. No other specimens were available to check this result which would indicate that residual tension stresses from tempering do not disappear under fatigue loading, and may, therefore, have an effect on the fatigue strength.

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BENDING specimen No. 642 of shot-blasted wire had run 13 million reversals at 85,000 lb. per sq. in. The only two measurements obtained on this specimen were zero and 56,000 lb. per sq. in. longitudinal compressive stress. No other specimens were available for check measurements. It would appear that the heavy compressive stress due to shot-blasting does not remain under fatigue stressing and consequently tests to 20 or 30 million cycles might give lower fatigue values than those obtained.

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(*f*) *Coiling Stresses.* After coiling as-received wire in a 2-in. diameter

TABLE 4—LONGITUDINAL RESIDUAL STRESSES IN WIRE AS RECEIVED[a]

Diameter of wire, in.	0.187	0.225
Kind and location of stress:		
Inside edge of coil, tension	180,000	90,000
Outside edge of coil, compression	70,000	120,000
Flat side (1), tension	40,000	30,000
Flat side (2), tension	15,000	20,000

[a] All values in lb. per sq. in.

coil, heavy residual longitudinal tensile and compressive stresses were present on the inside and outside of the coil respectively. Bluing reduced these stresses to about one-third their original value, but they were still appreciable in magnitude.

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7—Conclusion

THE zero-to-maximum torsion endurance limits of 110,000, 107,000 and 100,000 lb. per sq. in. for as-received wire are about 70 per cent higher than the values of 68,000 and 58,000 lb. per sq. in. estimated from the results of experiments on completed springs of similar material by F. P. Zimmerli (12). Residual tension stresses at the inside of the coils, even if they were shown to be present after the bluing treatments, would not be sufficient to explain such large differences in fatigue strengths, as Buehler and Buchholtz' results 20 per cent due to internal stress. (29) show variations of only 15 or

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THE results given in this paper may be considered as ideal values as it is possible to attain if no serious flaws are present. The twelve 0.225-in. specimens tested in zero-to-maximum torsion, the results of which are plotted in Fig. 18, represent a total length of not over 12 in. of wire actually submitted to the repeated stressing. In a single complete spring, possibly 40 in. of wire would be under test and if there were only one flaw in each spring such as that in specimen No. 350, indicated in Fig. 18, it is obvious that lower fatigue values would be obtained in the tests on complete springs. The only remedy for such a condition would be the elimination of all serious flaws in the material.

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COMPARISON may also be made with Swan, Sutton, and Douglas torsion results (11) on straight specimens of 0.182-in. diameter tempered Swedish wire with natural surface. The present zero-to-maximum value of 110,000 lb. per sq. in. for 0.125 in. wire is about 70 per cent higher than the results of their tests which were made at a ratio of minimum-to-maximum stress of 1:4.

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THE consistently high values of torsion endurance limit obtained for three sizes of wire in the experiments reported in this paper might suggest the presence of some consistent error in the work. However, the tests were made on three machines which were separately calibrated statically; calibration factors agreed closely and test results for the same wire on different machines were consistent among themselves.

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ALTHOUGH ratios of reversed-torsion fatigue strength and of zero-to-maximum torsion fatigue strength have been obtained for 0.187 in. and 0.225 in. wires and given in Table 3, it has not been possible to correlate these ratios with the factors which largely determine them, such as the shape of inclusions and of surface flaws. The extent and relative effect on bending and torsion fatigue strengths of anisotropy due to the drawing process has not been investigated. The effect of residual stress, if present, on the ratio of bending and torsion fatigue strengths would appear to call for investigation. Until information is available in the directions indicated it is not apparent that the bending fatigue strength of a wire will be a certain measure of the torsion fatigue strength of that wire.

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Acknowledgment

THE tests reported in this paper were sponsored by the A. S. M. E. Special Research Committee on Mechanical Springs, and were carried out through the Engineering Research Department of the University of Michigan, Ann Arbor. Acknowledgment is here made to members of the subcommittee, in particular to F. P. Zimmerli, to Profs. A. E. White and E. L. Eriksen for assistance of various kind, and to Prof. S. Timoshenko for helpful criticism and suggestions. Full responsibility for results or statements, however, is taken by the author.

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(*Please turn to page 588*)

A Bend Tester for Vacuum Tube Wires

By W. J. Farmer
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Bell Telephone Laboratories, New York, N. Y.

A VACUUM tube that spends its days and nights in a telephone repeater, firmly mounted in a steel-and-concrete building, has a much easier life than its fellow in a radio set, jostled and bounced in an airplane or a police car. With the growing use of Western Electric tubes in these mobile installations, more severe requirements had to be met by the mechanical structure of the tubes. Strains encountered in handling and shipping the tubes must be withstood while too much rigidity of the internal structure tends to transmit to the electrodes vibrations encountered in service and so to produce microphonic noise-currents. In manufacture, the growing complexity of tubes calls for close and accurate spacing between elements. These are supported from the glass envelope by wires bent into the desired form by a tool or mechanism which is so designed that when its force is removed the wire will spring back exactly to the proper configuration. Thus considerations of manufacture, shipment and use all require close control of the stiffness of the supporting wires.

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OVER many years the hardness of wires for vacuum tubes has been designated by manufacturers as "quarter hard" or "one hole hard" and some such designation has been used in purchase specifications. For the purchaser to check a specimen of wire against this sort of description was impossible. Feeling the need for a test which could be readily applied by both buyer and seller, and which should have some relation to the actual use of the wire, the Vacuum Tube Development Department investigated a number of such tests which had been proposed by manufacturers or users of wire. All of these had limitations which made it difficult to reproduce their results.

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EVENTUALLY a machine was designed to bend a sample by the force of a known and reproducible impact, and a model was built in the Development Shop of the Laboratories. The commercial design of such a machine, to cover the complete diameter and length range of support wires in which we were interested, was undertaken by the Materials Engineering group. The resulting machine is shown in Fig. 1; it is designed primarily for measuring the bend which a test sample will receive when it is struck by a mass falling from a given height. A reading on the dial gives the bend in degrees.

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SUPPORT wires whose temper lies within the useful range, whose lengths range from 1 centimeter to 5 centimeters, and whose diameters are from .003 in. to .125 in. can be tested. The energy of impact may be varied in two ways: first, by increasing the angle through which the pendulum falls from 20° to 120° in half degree steps and, second, by maintaining a constant angle of fall of the pendulum, but varying the distance from the center of the pendulum weight to the center of rotation. The machine weighs approximately 15 pounds and occupies a space of approximately 1 cubic foot. A handle is incorporated which affords ease in carrying the tester to any location in the shop, inspection department or laboratory. The only adjustment necessary before making a test, besides setting the pendulum weight and the angle of fall, is to level the machine; this is accomplished by manipulation of the leveling screws and is indicated by spirit levels.

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THE procedure in conducting an inspection test on a shipment of wire as received from a source of supply may be briefly described as follows: Upon referring to the specification under which the material was purchased, the striking edge is located on the pendulum arms to the specified distance from the edge of the jaws and the latch device which holds the pendulum is set at the specified angle of fall. The test sample is then clamped vertically between the jaws. The release latch is operated and the pendulum falls, striking and bending the sample. Since the pendulum must

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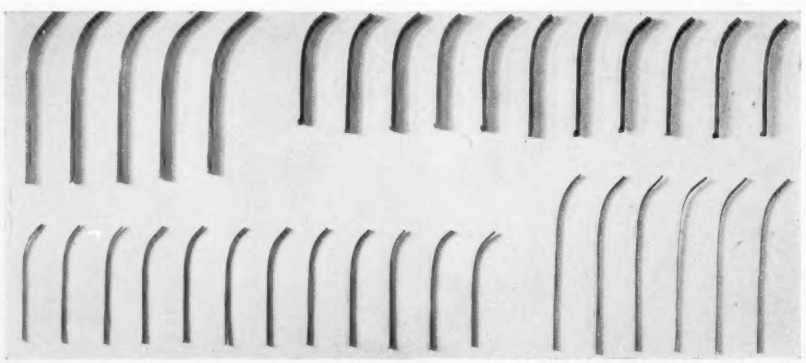

Fig. 1. Bent Specimens Illustrating Uniformity of the Tests.

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A Review of Recent Wire Patents

No. 2,015,714, CABLE, Patented October 1, 1935 by William A. Del Mar, Greenwich, Conn., assignor to Habirshaw Cable & Wire Corporation, New York, N. Y., a corporation of New York.

This cable includes a core of copper wires surrounding which is a rubber compound with a moisture and ozone resisting sheath for the rubber compound, comprised of vulcanized oil and other ingredients, the vulcanized oil predominating in proportions over the other ingredients. Surrounding this sheath is the ordinary rubber filled tape and braid or lead sheath.

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No. 2,016,610, BOLT, Patented October 8, 1935 by Isak Moeller, New Glasgow, Nova Scotia, Canada.

More specifically the inventor has endeavored to provide a water-proof bolt having a head which is undercut to provide a sharp edge and a water seal about the head. Annular ridges are provided on the bolt shank in order to block the entrance of water into the bolt hole, the ridges being formed of two meeting, frustro-conical faces, one being longer than the other.

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No. 2,016,872, SPRING STRUCTURE FOR MATTRESSES AND THE LIKE, Patented October 8, 1935 by Alex H. Olson, Evanston, Ill., assignor to Joseph W. Droll, Chicago, Ill.

The construction includes an upper and a lower frame, one of which comprises a horizontal series of parallel wire coil members and rows of mated pairs of wire springs extending between the two frames and longitudinally of the wire coil members of the one frame.

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No. 2,016,900, WIRE COATING MACHINE, Patented October 8, 1935 by Joseph H. Humberstone, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York.

This machine first partly folds a tape about the wire after the latter has come into contact with paste, after which the folded tape is directed so that its edges will approach one another, whereupon the tape is pressed tightly against the wire.

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No. 2,017,014, SPIRAL FABRIC, Patented October 8, 1935 by Clarence E. Pink, Cambridge, Md.

In this wire fabric, a chain selvage is provided of folding length of which the bights of one engage the eyes of the next, the terminal convolutions of the wire coils making up the belt passing through the eyes of the links and the cross wires entering the bights and being interlocked with the terminal convolutions therein.

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No. 2,017,032, CUSHION SPRING ASSEMBLY. Patented October 8, 1935 by William E. Wunderlich, Muncie, Ind., assignor to The Moore Company, Muncie, Ind., a corporation of Indiana.

The invention lies in the provision of upright parallel coil springs of special

Complete Descriptions and Drawings of Patents May Be Had for 25 cents. Address, Wire & Wire Products, 17 East 42nd St., New York.

construction wherein the intermediate convolutions are vertically aligned with the end convolutions and having their common axis offset from the principal axis of the terminal convolutions toward the margin of the assembly so that the margin of the assembly is filled out and reinforced while the terminal convolutions extend inwardly of the spring assembly to a point laterally offset and materially spaced from the intermediate convolutions.

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No. 2,017,607, INSULATED ELECTRICAL CONDUCTOR, Patented October 15, 1935 by Alfred Rheiner, Basel, Switzerland, assignor to the firm of Chemical Works Formerly Sandoz, Basel, Switzerland.

A wire conductor is provided with an insulation containing a cellulose acetate of the group consisting of the mono- and di-acetates prepared from natural cellulose material without alteration of the original fibrous structure of the latter.

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No. 2,017,657, CONTINUOUSLY LOADED CONDUCTOR, Patented October 15, 1935 by James E. Harris, Newark, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York.

Included in this assembly is a heat treated ferro-magnetic metal covered copper wire whose copper portion consists of commercial copper substantially completely freed of copper oxide.

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No. 2,017,952, CHAPLET, Patented October 22, 1935 by Ralph Ditty, Shaker Heights, Ohio, assignor to The Federal Foundry Supply Company, Cuyahoga Heights Village, Ohio, a corporation of Ohio.

The shank of this chaplet comprises a solid central portion being polygonal in shape. Outwardly extending portions are provided terminating in edges formed in a manner to be easily fusible by heat.

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No. 2,018,177, METHOD OF EQUIPPING BOX BINDING WIRES WITH FASTENING MEANS, Patented October 22, 1935 by Joseph Kruft, Rockaway, N. J., assignor to Stapling Machines Co., a corporation of Delaware.

The method consists in bending a piece of wire to form a U-shaped bight, coiling each end of the piece of wire to provide an enclosed opening within the coil through which the wire on the box part may be passed, and passing the wire on the box part upwardly through the opening in one coil and downwardly through the opening in the other coil.

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No. 2,018,211, WIRE DRAWING MACHINE, Patented October 22, 1935 by Henry J. Hogue, Lakewood, Ohio, assignor of one-third to Charles L. Wasmer and one-third to John C. Wasmer, both of Lakewood, Ohio.

Included in the construction is a reciprocating wire-drawing die and an oscillating lever for actuating this, the lever being connected with actuating mechanism separate from the fabricating machine with which it is associated and arranged on the opposite side of the fabricating machine from the wire drawing device.

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No. 2,018,404, METHOD OF TREATING STRANDS, Patented October 22, 1935 by Leslie F. Lamplough, Baltimore, Md., and Curtis E. Plass, East Orange, N. J., assignors to Western Electric Company, Incorporated, New York, N. Y., a corporation of New York.

In order to weatherproof the textile insulation about wire conductors, these inventors impregnate the conductor with a heated asphalt compound, then slightly cool the conductor and apply a coating of heated liquid wax, after which the conductor is coated with anti-sticking material.

✦ ✦ ✦

No. 2,018,461, MULTIPLE CONDUCTOR SECTOR ELECTRIC CABLE, Patented October 22, 1935 by Neil L. Morgan, Mount Royal, Quebec, Canada, assignor to Western Electric Company, Incorporated, New York, N. Y., a corporation of New York.

The method comprises stranding the component wires of each individual conductor into helices with spaces between layers of adjacent helices of wire, the alternate layers of the helices being stranded in opposite directions, wrapping insulating tapes around the conductors while still in substantially round shape, then stranding the conductors together and forcing them together through a die to obtain the sector form in one operation.

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No. 2,018,839, MACHINE FOR SEALING WIRE IN A WOODEN MEMBER, Patented October 29, 1935 by Joseph Daniel Coughlin, New York, N. Y., assignor to Jaydel Novelty Manufacturers, Inc., a corporation of New York.

This machine is adapted for driving a wire member into the end of the wooden member and then folding the fibers of the wooden member about the wire.

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No. 2,019,128, WIRE-HANDLING MACHINE, Patented October 29, 1935 by Isidor J. Furst, Brooklyn, N. Y., assignor to Circle Flexible Conduit Company, Inc., Brooklyn, N. Y., a corporation of New York.

This reel structure includes a frame with a carriage slidably mounted on the frame and a pair of heads also slidably supported by the frame. The carriage may be attached to either head. An endless belt is provided supported by the frame.

Exports and Imports of Wire

Exports of Iron and Steel Wire Products in Sept., 1935 and Sept., 1934
(In gross tons)

	Sept. 1935	August 1935	Sept. 1934
Wire rods	2,200	2,692	1,293
Hoops, bands and strip steel	3,366	3,856	1,079
Plain black or galvanized iron or steel wire	2,548	3,900	3,237
Barbed wire and woven wire fencing	1,784	2,801	2,779
Woven wire screen cloth	73	96	164
Wire rope	307	260	219
Insulated iron or steel wire and cable—see analysis below			
Other wire and manufactures	298	399	444
Wire nails	830	962	875
Tacks	40	32	39
Other nails, including staples	190	236	241
Bolts, machine screws, nuts, rivets and washers	575	469	450
Total, these 11 classifications	12,211	15,703	10,820

Imports of Iron and Steel Wire Products Into the United States
(In gross tons)

Concrete reinforcement bars	494	481	161
Hollow bars and drill steel	177	110	150
Merchant steel bars	39	93	1,507
Wire rods	1,495	801	339
Barbed wire	1,931	1,656	533
Round iron and steel wire	308	251	138
Telephone and telegraph wire	.....	1	.....
Flat wire and strip steel	161	249	178
Wire rope and strand	190	156	139
Other wire	132	127	34
Hoops and bands	2,525	1,079	1,477
Nails, tacks and staples	2,237	2,112	599
Bolts, nuts and rivets	6	1	8
Total, these 13 classifications	9,695	7,117	5,263

EXPORTS
INSULATED WIRE AND CABLE, SEPTEMBER, 1935

	Foreign		To U. S. Possessions	
	Pounds	Dollars	Pounds	Dollars
Insulated iron or steel wire and cable	4,748	$ 755	1,214	$ 214
Rubber-covered wire	265,492	55,324	57,091	11,030
Copper weatherproof wire	112,452	13,742	27,192	4,237
Copper telephone cable	22,379	2,960	180,577	31,873
Other insulated copper wire	385,743	69,278	118,143	17,523
Nickel-chrome electric resistance wire	22,197	27,071	.....	.....
Total, these 6 classifications	813,011	$169,130	384,217	$64,877

THE highest tonnage of iron and steel products in two years was received by the United States during September when the import total registered 53,158 tons to advance 70 percent above the trade during the previous month, and some 112 percent over receipts during the corresponding month of 1934. The import aggregate over the elapsed 9 months has reached a total of 299,244 tons, registering an increase of 23.6 percent over receipts during the corresponding period of 1934.

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SCRAP iron and steel headed the list as the chief iron and steel product exported during the month (from a tonnage basis), as has been the case over a considerable period of time. The 170,486-ton trade was chiefly distributed among Japan 56,188, Italy, 40,432, the United Kingdom, 30,531, Rumania, 12,291, and Canada, 7,830. Tin plate and taggers' tin continued to rank second in importance with an aggregate of 11,397 tons finding numerous outlets, chief among which being China, 1,565, Japan, 1,226, Brazil, 1,224, the Philippine Islands, 970, and Hong Kong, 899. The 7,858-ton trade in black steel sheets also found numerous markets, outstanding among which were Canada, 3,766, Australia, 1,245, Mexico, 1,061, and Brazil, 410. Galvanized steel sheets, 5,039 tons, made up the fourth product of importance and went principally to the Philippine Islands, 1,295 tons, the Union of South Africa, 569, Canada, 445, Greece, 392, and Colombia, 361, in a widespread trade. Plain structural shapes with a total of 4,194 tons followed and found outlet chiefly in Canada, 2,982, Cuba, 289, and the Philippine Islands, 229. The sixth product was 'other plate' shipped to a total of 3,935 tons, the outstanding purchasers being Mozambique, 1,323, Canada, 829, Cuba, 288, Mexico, 274, and the Philippine Islands, 256.

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JAPAN continued to be the leading outlet on a tonnage basis, although its purchases of 63,607 tons represented the lowest volume received since February, 1934. This trade for the most part took in 56,188 tons of iron and steel scrap, 2,245 tons of tin plate scrap, 1,750 tons of heavy rails, 1,226 tons of tin plate, 1,137 tons of ingots, blooms, etc., and 667 tons of waste-waste tin plate. Italy ranked next, its total of 40,475 tons practically all confined to iron and steel scrap. The United Kingdom followed with purchases aggregating 31,256 tons, of which the chief items were iron and steel scrap, 30,531, hot rolled strip steel, 288, cold rolled strip steel, 103, and black steel welded pipe, 99. Canada's more varied trade involved 27,489 tons made up principally of iron and steel scrap, 7,830, black steel sheets, 3,766, plain shapes, 2,982, skelp, iron or steel, 2,892, steel bars, 1,891, hot rolled strip steel, 1,662, and cold rolled strip steel, 1,162. The 12,295-ton trade with Russia was almost all confined to iron and steel scrap as was the 10,287 ton trade with Belgium, the sixth market.

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PIG iron at 14,357 tons led as the chief product moving in the import trade from a tonnage standpoint, the chief countries of supply being the Netherlands, 5,782, British India, 5,227, and Germany, 2,538. Following was scrap, 11,226 tons, practically all purchased from Canada, 11,126, while the 4,256-ton total for ferromanganese and spiegeleisen ranked

(*Please turn to page 581*)

Exports and Imports

(*Continued from page 580*)

next, coming for the most part from Canada, 1,608, Norway, 1,395, Germany, 445, and France, 375. Next in importance was the 2,766-ton total for structural shapes, Belgium, 2,544, leading in the supply of this item, with France sharing to the extent of 141 tons. 'Other hoops and bands' were received to the extent of 2,525 tons, and came chiefly from Belgium, 1,619, France, 472, and Germany, 382. The sixth product of importance was cotton ties imported to a total of 2,347 tons, the Netherlands, 1,527 tons, leading in the supply of this item, followed by Germany which accounted for 796 tons.

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Where September Receipts Came From

CANADA maintained its lead in the supply of iron and steel products to the United States — from a tonnage standpoint—during September, its aggregate shipments of 13,413 gross tons being made up chiefly of scrap, 11,126 ferromanganese and spiegeleisen, 1,608, pig iron, 457, and 'other pipe', 135. Germany ranked next with a total of 12,207 tons involving a rather varied trade in which the outstanding items were pig iron, 2,537, nails, tacks, and staples, 1,944, barbed wire, 1,833, welded pipe, 1,439, sheets, skelp, and sawplate, 1,068, and 'other pipe', 868. Belgium followed, the chief products moving in its trade of 8,731 tons involving structural shapes, 2,544, 'other hoops and bands', 1,619, bars, whether solid or hollow, 1,291, sheets. skelp, and sawplate, 1,112, and wire rods, 504. The share of the Netherlands, 7,321 tons, brought it into the position of the fourth supplier of the month, and this trade for the most part was made up of pig iron, 5,782, and cotton ties, 1,528. British India's participation of 5,227 tons was all of pig iron, while Norway—the sixth ranking supplier—shared to the extent of 2,079 tons, confined principally to ferromanganese and spiegeleisen, 1,395, pig iron, 337, and steel ingots, blooms, etc.

A DECREASE occurred in receipts of **card clothing**, the 14,500 square feet valued at $16,-742 declining 7,216 square feet and $1,761 from August totals. This trade was covered by the United Kingdom, 10,756 square feet valued at $11,402, the Netherlands, 3,654 square feet valued at $4,818, and Germany, 90 square feet valued at $522.

WIRE cloth and screening receipts aggregating 59,168 square feet gained 3,203 square feet over the earlier month trade, and came from Germany, 29,737 square feet, Canada, 11,881 square feet, Czechoslovakia, 10,681 square feet, and the Netherlands, 6,869 square feet.

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(*Please turn to page 587*)

Wins instant approval!

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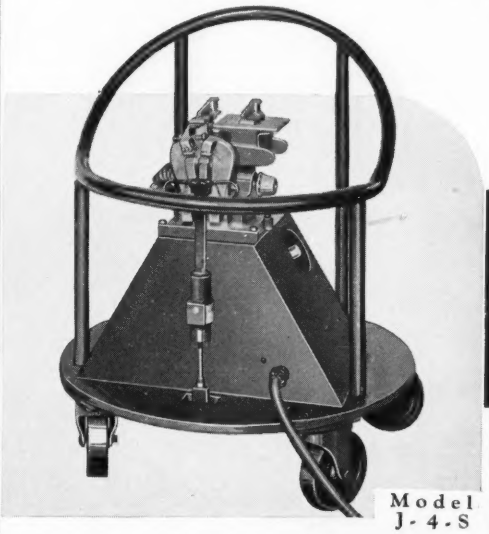

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Height to welding dies—23".

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C. Hix Jones Asst. District Manager Youngstown Sheet and Tube Company

THE Youngstown Sheet & Tube Co. today announced the appointment of Mr. C. Hix Jones of its Detroit office as assistant district manager of the Detroit district. It also announced that Harold M. Pierce, for the past five years with the Newton Steel Co., has joined the Detroit organization of Youngstown Sheet & Tube.

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U. S. Civil Service Metallurgist Examinations

THE United States Civil Service Commission has announced open competitive examinations for metallurgist positions as follows:

✦ ✦ ✦

APPLICATIONS for associate and assistant metallurgist (recovery) and associate and assistant metallurgist (physical) must be on file with the U. S. Civil Service Commission, Washington, D. C., not later than December 9, 1935.

✦ ✦ ✦

THE entrance salary for the associate grade is $3,200 a year, and for the assistant grade $2,600 a year. These salaries subject to a deduction of 3½ per cent toward a retirement annuity. Optional branches are: Ferrous, nonferrous, and ore dressing.

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CERTAIN education and experience are required.

✦ ✦ ✦

FULL information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post office or customhouse in any city which has a post office of the first or the second class, or from the United States Civil Service Commission, Washington, D. C.

✦ ✦ ✦

Electric Annealing Furnaces For Ford Motor Company

THE Ford Motor Company has purchased 12 annealing furnaces together with 36 bases and metal hoods from the Westinghouse Electric & Manufacturing Company for use in conjunction with their new strip mill.

'Round the World With the Wire Industry

THE prediction that Japan would lose in this year a very great proportion of her export trade has come out right. For example, Japanese exports of wire nails to India during the first eight months of this year declined from 8,117 tons in 1934 to only 2,187 tons; those to Siam from 887 tons to 318 tons; and to the Dutch Indies from 2,977 tons to 635 tons. The reasons for this decline are the following: Prices have advanced in Japan, the Japanese works are holding back having suffered heavy losses in past two years, and the customers are dissatisfied with Japanese wire nails and other products, the quality being too poor.

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THE German wire rope cartel reports that development of the export trade continues to be satisfactory. The present export figures for wire ropes are approximately 32% better than last year and the monthly figure is superior to 1300 tons.

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THE general export movement for wire products remains unaltered compared with previous months. The demand in Africa and the Far East has improved. Italy has bought wire machinery in Germany and also wire products, as Germany will execute all orders placed by Italy with German manufacturers and has nothing to do with sanctions, the heavy Italian purchases will probably continue.

✦ ✦ ✦

CARD clothing manufacturers have established a cartel. The German export business in card clothing to the United States will be fostered by the manufacturers. It is said that competition with the British industry is easily possible, as British prices have recently advanced.

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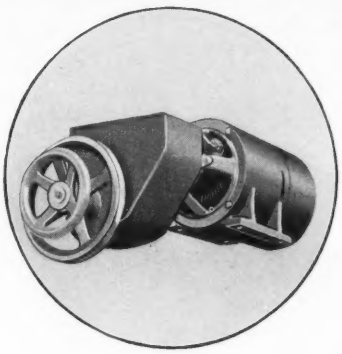
AMONG recent barter transactions it is noteworthy to report an order for 2100 tons of wire products, chiefly fencing, from South Africa against wool and ores, and a further order for £23,000 worth wire ropes from South African Rand Mines also against South African products. Prices on the export market as a whole are unaltered, with the exception of wire netting, which shows a further rise. Germany has accepted an order from a French company in Djibuti for 30,000 reels of barbed wire for Abyssinia, ship-

(*Please turn to page 584*)



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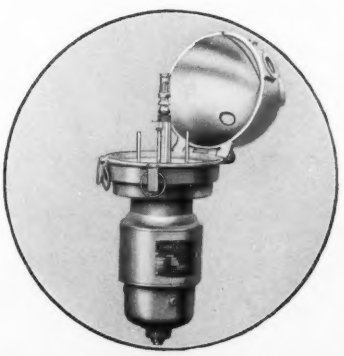

SYNCRO

'Round the World With the Wire Industry

ment is taking place as quickly as possible, net cash being paid.

✦ ✦ ✦

German Exports of Stainless Steel Wire

THE export demand for stainless steel wire is remarkable. Markets which formerly never placed orders for this quality of wire are now ordering. The present price is between 18½ and 20 cents per pound, f.o.b. The chief markets are Scandinavia, Holland, and the Baltic states, but Spain and Portugal are also buying.

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German Domestic Wire Business Good

THE domestic wire business continues satisfactory. This concerns particularly the wire nail trade, as the demand for wire nails is very heavy due to the large building operations, which are going on virtually in all markets of Germany. The wire nail industry is operating at present at 78% of its capacity, the fencing wire industry at 65%, the wire netting at 70%, the barbed wire at 75%, and the small wire ware industry at 60% of its capacity. The export share is in the neighborhood of 38%.

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New Steel Plant Registered In India

THE Bengal Steel Company was registered during August with a capital of 150,000,000 rupees, for the purpose of erecting and operating a steel mill in the province of Bengal.

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WORK on the National Iron and Steel Company, Ltd., which was registered in October, 1934, with an authorized capital of 5,000,000 rupees for the purpose of erecting a re-rolling plant at Belur near Calcutta under joint Indian and Japanese capital, has been held up for some time due to certain difficulties but is again progressing and production, it is stated, will probably begin by the first of December.

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Expansion of Australian Iron and Steel Industry

TWO outstanding announcements were made by the Chairman of Directors of the Broken Hill Proprietary Company, Ltd., of **Australia,** with regard to the future expansion of the company: (1) Increase of capital and (2) the negotiations which were proceeding for the acquisition of the whole of the ordinary shares of the Australian Iron and Steel Ltd., in exchange for a parcel of shares of the Broken Hill Proprietary, Ltd., thus confirming rumors which have been circulating concerning this merger.

Sleeper & Hartley
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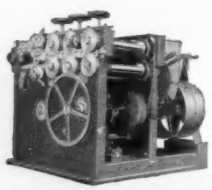
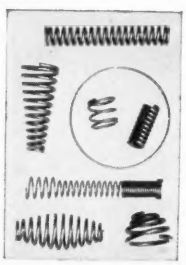
DESIGNERS OF "THE MACHINES THAT PUT THE 'RINGS' IN SPRINGS"

UNIVERSAL SPRING COILERS IN FOURTEEN SIZES!



UNIVERSAL SPRING COILING MACHINES are built in fourteen sizes, handling cold, oil-tempered wire from .004" to ⅝" diameter. Produce an extraordinary variety of spring forms (a few of which are seen at the right) at high speeds. The machines are offered in two types, both of which automatically close and square the end coils as desired. Bulletin Nos. 101 and 101-A give full details.



In addition to many other standard spring and wire coiling machines, spring-hooking, and spring-setting machines we offer:—
Book Spiral Coiling Machines. Bearing Spiral Machines.
Flat Ring Coiling and Edgewise Coiling Machines.
Torsion Spring Machines. Lockwasher Machinery.
Flexible Casing and Flexible Metallic Tubing Machines.
Rolling and Flattening Mills and Take-Ups.
Wire Nail Machines. Wire Reels.
Wire Drawing and Wire Spooling Machinery. Wire Mill Equipment.

'Round the World With the Wire Industry

Expansion Contemplated by United Kingdom Manufacturers

A MODERN bar and rod mill to be ready for operation about May or June, is being planned by Colvilles, Ltd., the most important Scottish steel company. The **English** Steel Corporation is busy re-equipping some of its old works in Sheffield, which were closed down when rationalization took place. Orders are said to be coming in so rapidly that production is having some difficulty in keeping up with demand. A new mill for the hot-rolling of strip steel, which is claimed to be the best and most up-to-date in the country, has been put down by another Sheffield firm, Messrs. Arthur Lee & Sons. A movement is reported to be on foot having as its object the reopening of the steel works in Ebbw Vale, an area in South Wales where the industrial depression has caused great distress. The works, at which about 10,000 men were employed, have been closed for nearly six years.

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A NEW three-high hot rolled strip mill was completed at the works of Ductile Steels, Ltd., in the Birmingham, England, district during September, claimed to have been made possible by reason of the existing protective iron and steel tariffs in Great Britain.

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Slow Development in Brazilian Iron and Steel Industry

THE **Brazilian** iron and steel industry was founded many years ago but development has been slow. The principal company which has been active in this industry is the Companhia Siderurgica Belgo-Mineira, a Belgian organization, and this company at present has two high temperature blast furnaces with a daily capacity of 100 tons of pig iron; three Martin furnaces with capacity to transform all the steel made into round, flat and other bars of every description; as well as a wire factory. Its present annual production amounts to around 35,000 metric tons of pig iron, 30,000 tons of laminated steel and 3,000 tons of billets. It is stated that a new modern iron and steel plant is to be erected on the property of the company in question at Monlevade in the State of Minas Geraes, to have a total annual capacity of 100,000 tons of rolled steel in all shapes and sizes, including steel rails for railroads. It is expected that the plant will be completed in about five years, and consequently, will not be in full operation before 1940, when it will be in a position to supply a large part of Brazil's needs in iron and steel, it is stated.

✦ ✦ ✦

Swiss Foundry, Rolling Mill and Wire Production

POOR occupation in the numerous domestic iron foundries of Switzerland, caused prices of

(*Please turn to page 587*)

HIGH-SPEED
UPRIGHT CONE WIRE DRAWING MACHINES

DEMAND YOUR CONSIDERATION WHEN THE QUESTION OF REPLACING WORN OUT AND OBSOLETE EQUIPMENT ARISES, DUE TO--

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Waterbury, Connecticut

OFFICES
CLEVELAND CHICAGO PHILADELPHIA

G. E. Clifford Republic Sales Manager In Los Angeles District

GEORGE E. CLIFFORD has been appointed district sales manager of Republic Steel Corporation in the Los Angeles, Calif., district, according to an announcement by N. J. Clarke, vice president in charge of sales for Republic. Mr. Clifford was appointed following the resignation of George F. Emanuels who has been in charge of Republic's Los Angeles office for several years.

✦ ✦ ✦

MR. CLIFFORD attended the University of Pittsburgh, class of 1918, but left college in 1917 to join the Royal Flying Corps. He received his discharge from the Corps in December, 1918. From February, 1919, until 1925 he was connected with the sales department of the Atlas Powder Company, at Pittsburgh, Pa. He then became district representative in Cincinnati, Ohio, for the A. M. Byers Company. Two years later he was made manager of central district for Byers and afterwards was made manager of their Pittsburgh district. He joined Republic Steel Corporation in August, 1930, as assistant manager of sales in the pipe division.

✦ ✦ ✦

THE promotion of Mr. Clifford enables him now to devote his time to the direction of sales of all Republic products in the Los Angeles territory.

✦ ✦ ✦

Donald Philip Doyle

"DONALD PHILIP DOYLE, comptroller of the General Cable Corporation, died at his residence, 14 Sherman Avenue, Gedney Farms, October 29th after a brief illness, with pneumonia. Mr. Doyle was in his 40th year.

✦ ✦ ✦

MR. Doyle is survived by his wife, Mrs. Elizabeth A. Field Doyle; a son, Donald, Jr., and a daughter, Diane, of this city, and his parents, Mr. and Mrs. Donald Bronson Doyle, of Middlebury, Conn.

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MR. Doyle was born in Winsted, Conn., and attended schools there and at Torrington, Conn., and Worcester, Mass. He was with the Sterling Products Company at Cleveland when the General Cable Corporation was formed in 1927 and he joined that organization as Comptroller at that time. The office of the Comptroller was moved to this city in 1933, and Mr. Doyle took up his residence here.

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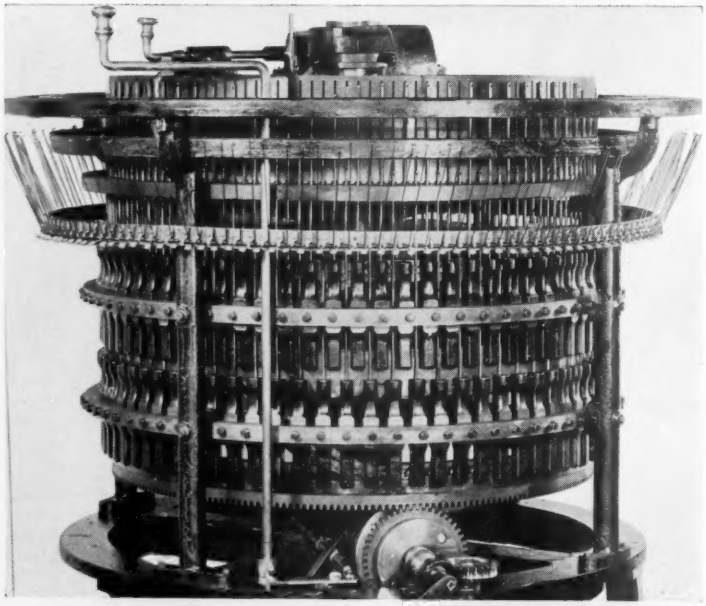
HE was an expert bridge player and was an official scorer for the National Bridge Association. In that capacity Mr. Doyle had handled many large bridge tournaments throughout the east.

✦ ✦ ✦

FUNERAL services were held at his late residence. The Rev. Arthur S. Wheelock officiated at the services. Interment was at Hope Cemetery, Worcester, Mass.

A NEW TYPE OF WIRE COVERING MACHINE!!



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F. D. SAYLOR & SON

13095A Greeley Avenue DETROIT, MICH.

Exports and Imports

(*Continued from page 581*)

THE upward movement in receipts of **fourdrinier and other paper making wire,** evident over the past several months, came to a halt when 64,134 square feet were imported during September to fall 24.2 percent under the trade during August. The principal participators in this trade were Austria, 31,258 square feet, and Germany 29,747 square feet.

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WIRE heddle imports aggregated 934,000 pieces, representing a sharp decline of 43 percent under receipts during the previous month. This total was supplied by France 500,000 pieces, Germany, 251 pieces, and Sweden, 2,080 pieces.

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THERE was no trade whatever in **wire fencing and netting** galvanized before weaving, which over the past several months had been received in diminishing amounts. With respect to the galvanized after weaving grade, 1,402,450 square feet were received, registering 55,180 square feet higher than the August trade. This aggregate was supplied by Belgium, 1,214,400 square feet, the Netherlands, 180,000 square feet, and the United Kingdom, 8,050 square feet.

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Round the World With The Wire Industry

(*Continued from page 585*)

cast-iron articles to approach those of the post-war period. The only material for which there was any considerable demand was cast-iron used in the building industry and this fell off heavily in comparison with the preceding year, because of the decline in building activity.

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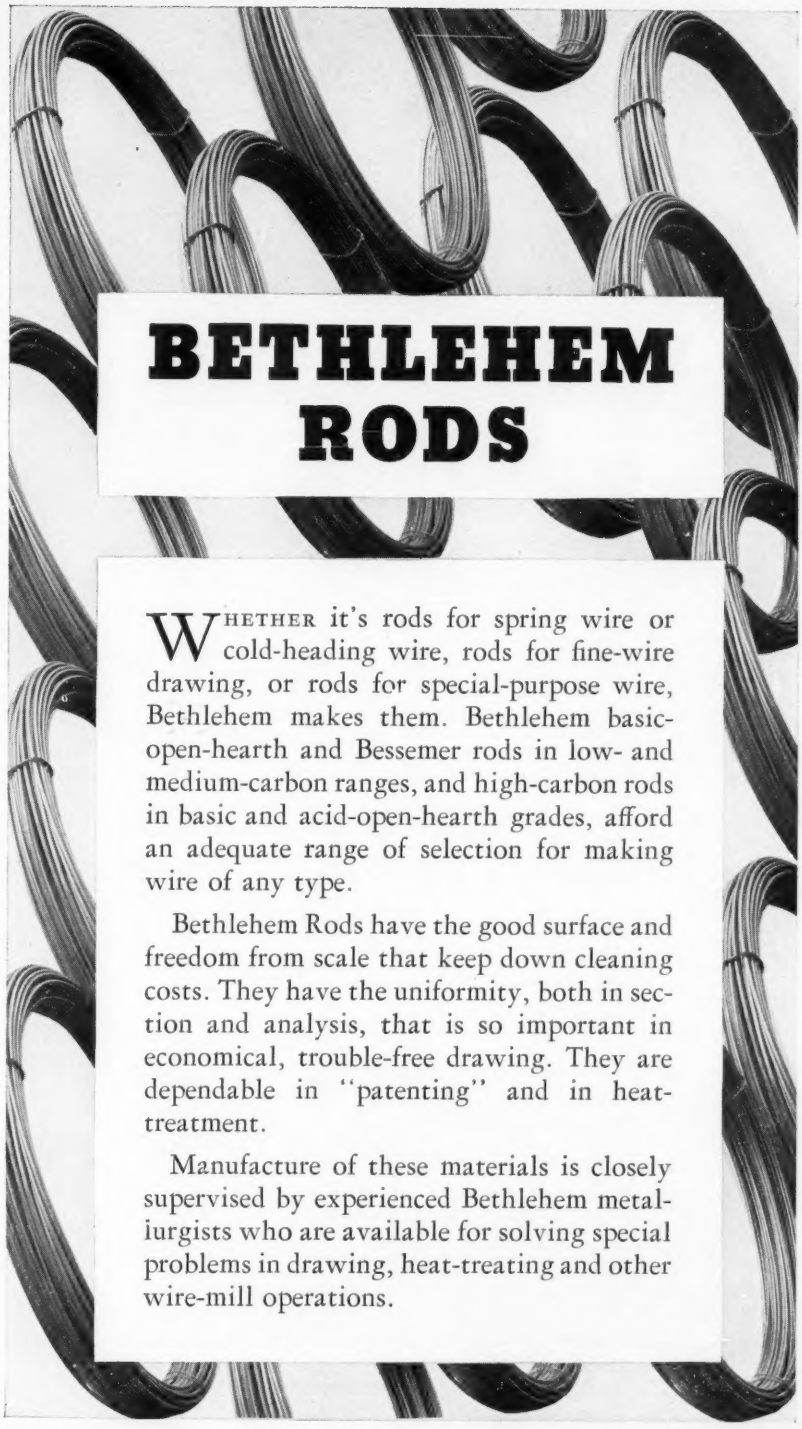
ROLLING mills were fairly occupied during the first half of this year, but subsequently there was a drop in orders, while sales of rolled iron and rolled iron products used chiefly in domestic buildings, manufacturing, and agriculture did not reach the volume of the preceding year.


BETHLEHEM
RODS
WHETHER it's rods for spring wire or cold-heading wire, rods for fine-wire drawing, or rods for special-purpose wire, Bethlehem makes them. Bethlehem basic-open-hearth and Bessemer rods in low- and medium-carbon ranges, and high-carbon rods in basic and acid-open-hearth grades, afford an adequate range of selection for making wire of any type.
Bethlehem Rods have the good surface and freedom from scale that keep down cleaning costs. They have the uniformity, both in section and analysis, that is so important in economical, trouble-free drawing. They are dependable in "patenting" and in heat-treatment.
Manufacture of these materials is closely supervised by experienced Bethlehem metallurgists who are available for solving special problems in drawing, heat-treating and other wire-mill operations.

Bethlehem District Offices are located at: Atlanta, Baltimore, Boston, Bridgeport, Buffalo, Chicago, Cincinnati, Cleveland, Dallas, Detroit, Houston, Indianapolis, Kansas City, Milwaukee, New York, Philadelphia, Pittsburgh, San Antonio, St. Louis, St. Paul, Washington, Wilkes-Barre, York. *Pacific Coast Distributor:* Pacific Coast Steel Corp., San Francisco, Seattle, Los Angeles, Portland, Salt Lake City, Honolulu. *Export Distributor:* Bethlehem Steel Export Corp., New York.

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY

GENERAL OFFICES: BETHLEHEM, PA.

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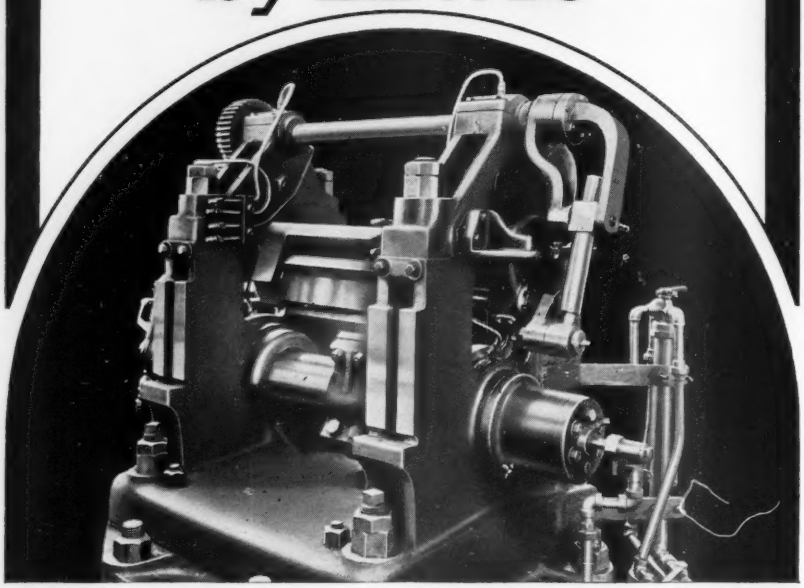

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The Correlation of Spring-Wire Bending and Torsion Fatigue Tests

(*Continued from page 577*)

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✦ ✦ ✦

Note: Statements and opinions advanced in this paper are to be understood as individual expressions of the author, and not those of the Society.

✦ ✦ ✦

A. A. Aranson Assistant To President Crucible Steel

F. B. HUFNAGEL, president of the Crucible Steel Company of America, announced today that Arthur A. Aranson has been appointed to the position of assistant to the president, effective November 1st.

✦ ✦ ✦

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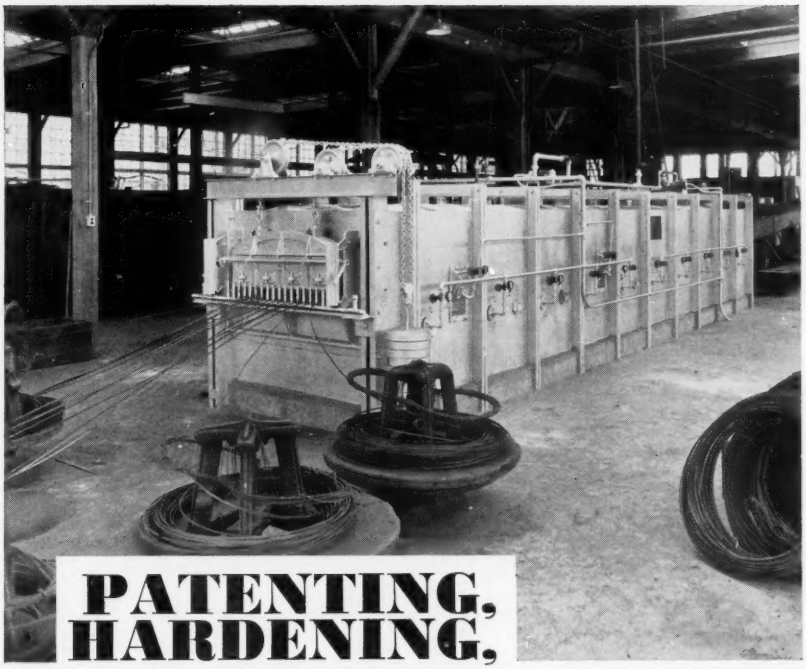

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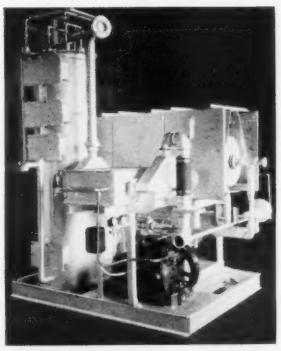

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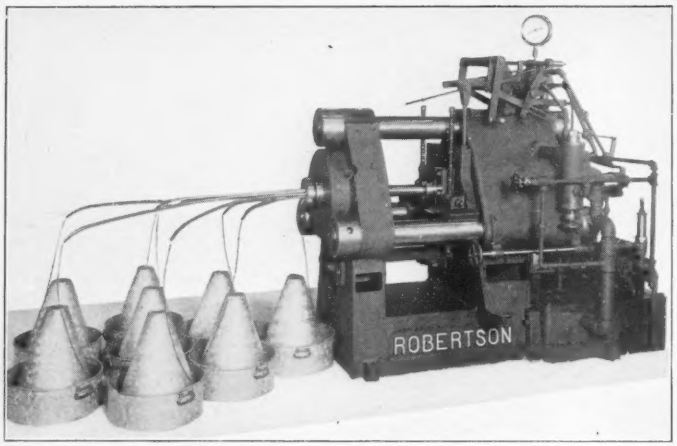

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Synopses of papers presented before the 27th Annual Autumn Meeting of the Institute of Metals of Great Britain held at Newcastle-on-Tyne Sept. 12, 1935.

Paper (703) on "Metal Losses in Melting Brass and Other Copper Alloys", by Maurice Cook, M. Sc., Ph. D., Member (I. C. I. Metals, Ltd., Witton, Birmingham.)

✦ ✦ ✦

A STUDY has been made of the metal losses which occur when such alloys as gilding metals, brasses, and cupro-nickel are melted in crucibles in coke-fired pit furnaces, and for this purpose figures have been obtained both from carefully controlled trials and from production runs, involving the melting of considerable quantities of material under different conditions.

✦ ✦ ✦

OBSERVATIONS have also been made on the metal losses occurring in melting brasses of different compositions under various conditions of fluxing in Ajax-Wyatt induction furnaces, and large-scale trials covering considerable periods and involving large tonnages of metal have been made. The loss is largely due to oxidation and the results of various methods of reducing the loss, such as varying the nature and amount of flux, the use of charcoal, coke, anthracite, and coal-gas, which have been tried are discussed.

✦ ✦ ✦

Paper (701) on "Observations of the Porosity and Segregation of Two Bronze Ingots", by N. P. Allen, M. Met., D. Sc. Member, (Lecturer in Metallurgy, University of Birmingham), and S. M. Puddephat, B. Sc., Member, (Metallurgical Department, University of Birmingham).

✦ ✦ ✦

THE distribution of porosity and the variation in copper content in two 10 per cent tin-bronze ingots have been found to be influenced principally by the flow of heat during solidification. There was a close connection between the porosity and segregation of the ingots.

✦ ✦ ✦

Paper (704) on "The Properties of Some Special Bronzes", by Professor D. Hanson, D. Sc., Vice-President, (Profes-

sor of Metallurgy, University of Birmingham), and M. A. Wheeler, (Department of Metallurgy, University of Birmingham).

✦ ✦ ✦

ADDITIONS of aluminum, manganese, aluminum plus manganese, iron and silicon have been made to copper-tin bronzes.

(1) Aluminum — Within the range of compositions investigated, alloys consisting of one solid solution work readily, hot or cold. Alloys possessing a duplex structure can be worked with much greater difficulty, and are specially difficult in hot-working. The range of compositions in which easy working properties can be obtained can be extended by annealing duplex alloys to give a homogeneous structure. Annealed alloys possess very good ductility; the maximum tensile strength attained in annealed alloys was 30 tons/in.^{2} in an alloy containing 4 per cent. aluminum and 5 per cent. tin. Alloys containing 2 per cent. or more aluminum are fairly resistant to oxidation at high temperatures, particularly if the cast surface is not damaged. Polished alloys have a pleasing appearance, and are fairly resistant to tarnishing in the air. The scale formed when the alloys are heated is very difficult to remove, either mechanically or by pickling processes.

✦ ✦ ✦

(2) Manganese—Manganese has a relatively small influence on the working properties of a 5 per cent. tin bronze. As much as 6 per cent. of manganese must be added before an appreciable embrittling effect is apparent. Alloys within the range of composition investigated can be worked hot or cold.

Manganese increases the softening temperature of the tin bronzes.

✦ ✦ ✦

(3) Aluminum and Manganese —Copper-tin bronzes containing aluminum and manganese, within the range investigated, are difficult to cold-work, without annealing, if the aluminum content exceeds about 0.25 per cent. With aluminum contents up to about 3 per cent. they may be cold-worked if they are previously rendered homogeneous in structure by an-

(*Please turn to page 592*)

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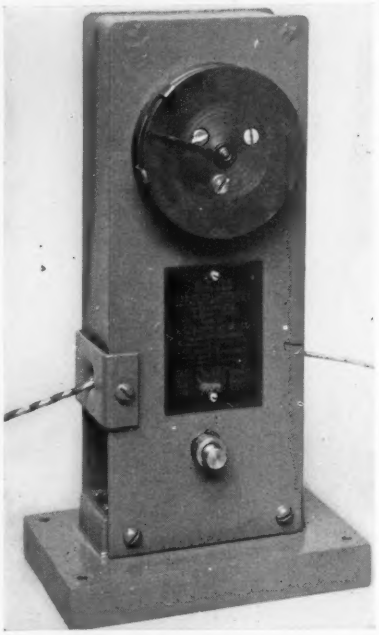

This machine when attached to a take-up will operate an automatic stop when a variation in diameter occurs. The pointer is grounded and the small metal ears attached to the discs are connected to a sparker. When the pointer is moved by a variation in diameter within sparking distance of the ears a spark will jump and stop the take-up. The amount of variation in diameter before the machine will stop can be varied to meet the purchasers requirements.

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Papers of Institute of Metals of Great Britain

(*Continued from page 591*)

nealing. Aluminum increases the tensile strength of manganese-tin bronzes, without appreciably reducing the ductility.

✦ ✦ ✦

(4) Iron—Iron, in the form of American washed iron, alloys readily with copper, and 4 per cent. of iron can be incorporated without difficulty. No trouble was experienced in obtaining good castings. Iron-tin-copper alloys containing 5 per cent, of tin and up to 4 per cent. of iron can be rolled, and the ductility decreases only slightly even when 3 or 4 per cent. of iron is present. Iron up to 1.5 per cent. has little effect on the tensile properties of a 5 per cent. tin bronze, but 2 per cent. or more of iron increases the tensile strength at the expense of the ductility. The iron is distributed uniformly throughout the solid alloy in the form of small particles, the structures being very similar to those of iron-copper alloys containing no tin. 4 per cent of iron greatly refines the cast structure of a 5 per cent. tin bronze.

✦ ✦ ✦

(5) Silicon—Silicon has a marked effect on the cold-working properties of a 5 per cent. tin bronze. An alloy containing 3 per cent. of silicon can be cold-worked only with great difficulty in the "as cast" condition; after annealing at 800°C. for 4 hours the cold-working properties are slightly increased. The addition of 4 per cent. of silicon to a 5 per cent. tin bronze renders the material unworkable both hot and cold. The addition of silicon greatly increases the strength of a tin bronze.

✦ ✦ ✦

Paper (700) on "An X-Ray Investigation of Certain Copper-Tin Alloys", by Professor E. A. Owen, M. A., D. Sc., Member, (Professor of Physics, University College of North Wales, Bangor) and John Iball, Ph. D., (University College of North Wales, Bangor).

THE oc-phase boundary of the copper-tin alloys has been determined by X-ray analysis betwen 750° and 300°C. Its position between 750° and 500°C. is moved in the direction of slightly higher tin content, but between 500° and 300°C. in the direction of lower tin content than that of the boundary as previously determined. The maximum solubility of tin in copper occurs at about 520°C., the temperature corresponding to the (β) to ($\alpha+\gamma$) transformation. The parameter of the γ-phase is found to lie between 17.917 and 17.924A at 480°C., but the measurements are not considered sufficiently extensive to decide whether there exists a definite region of solubility for this phase. The ε phase is a solid solution the range of which does not exceed 1.5 per cent. copper by weight at 380°C. The atomic volume of the copper saturated ε-phase at this temperature is found to be 14.124A.^{3}, and that of the tin-saturated phase 14.177A.^{3}. The results so far obtained suggest that a transformation of (γ) into ($\alpha+\varepsilon$) occurs at a temperature slightly higher than 300°C., and that the copper saturated boundary of the ε-phase is not exactly vertical between 380° and 300°C.

✦ ✦ ✦

Paper (710) on "Electron Diffraction Examination of Protective Films Deposited on Magnesium and Magnesium Alloys by the R. A. E. Dichromate Process", by H. G. Hopkins, A. R. C. S., B. Sc., (Physics Dept., Royal College of Science, London).

✦ ✦ ✦

THE protective films, in general, yielded diffuse diffraction rings. It is concluded that the films consist of very small crystals orientated at random. It is tentatively suggested that the diffracting lattice is pseudo-morphic magnesium oxide.

✦ ✦ ✦

Further Digests will appear in the January, 1936, issue of Wire and Wire Products.

A Bend Tester for Vacuum Tube Wires

(*Continued from page 579*)

strike the specimen only once, it is arrested manually as it swings back. The final step in the test is to move the pendulum toward the bent specimen until contact is indicated by lighting of a lamp or by a click heard in a telephone receiver. The amount of the bend is

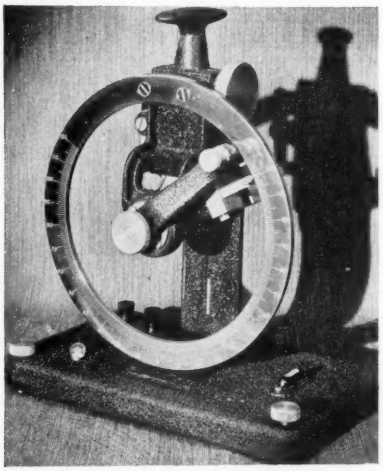

Fig. 2. Front View.

✦ ✦ ✦

then read directly from the dial with the aid of the pendulum index pointer. Experience has shown that the angle of fall and the distance from the striking edge to the jaw should be so arranged that the resultant angle of bend of the sample will be between 30° and 60°.

✦ ✦ ✦

SINCE the reliability of the method depends on the constancy of velocity of the pendulum, it is important that friction should be both small and constant. To this end the pendulum system turns in two self-aligning ball bearings. Were friction entirely absent the pendulum when swinging freely would rise to the same height as that from which it fell. A series of tests showed that the pendulum regained from 90.3 to 99.6 per cent of its initial height, the lower values being recorded for smaller initial heights and shorter radii of the striking edge. In all cases where the drop was from an angle

(*Please turn to page 594*)

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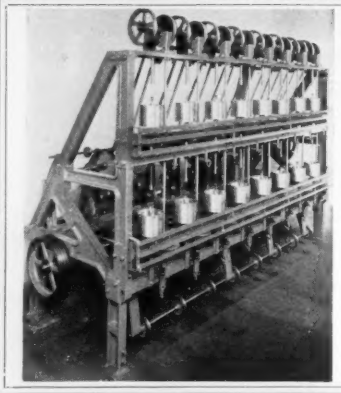

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A Bend Tester for Vacuum Tube Wires

(*Continued from page 593*)

of 50° or more, the height regained was greater than 95 per cent.

✦ ✦ ✦

IN order to determine whether or not results obtained with this machine are satisfactorily reproducible, specimens of straight, dead soft annealed nickel wire were tested at various lengths. Some of the bent specimens, illustrating the uniformity of the test, are shown in Figure 2.

✦ ✦ ✦

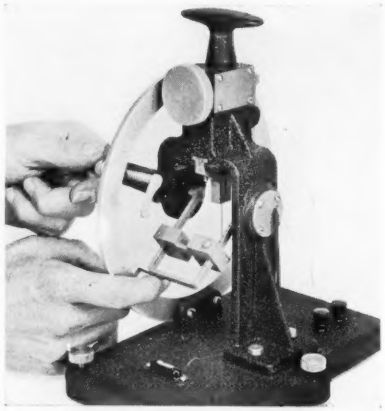

Fig. 3. Tester in Use. ✦ ✦ ✦

THIS machine can be used for control of hardness of temper of material for vacuum tubes, and for analysis of these materials after they have passed through manufacturing processes or have been in service for a period of time. It will also satisfactorily test wire of any temper or composition as well as sheet material 3/8 in. or less in width, the testing procedure being the same as described for the vacuum tube support wires.

✦ ✦ ✦

AT the annual meeting of the American Society for Testing Materials, held in Detroit during June of this year, the bend tester was exhibited and demonstrated. Much interest was shown at the time, and the machine has been recommended by a sub-committee of that Society for the testing of vacuum tube support wires. Tests of magnet wires have shown that the machine offers considerable promise as a specification instrument in that field.

New Machine for Producing Straight and Polished Rods in a Single Operation

(*Continued from page 559*)

entire process is automatic, and the material flows through the machine continuously.

✦ ✦ ✦

THE makers of the machine claim that it offers great economies in the manufacture of rods, and that the finished rods are perfectly straight and highly polished. Also, because the material moves uninterruptedly forward in a straight line, no disturbing inside stresses or knots occur in the rod. The grippers, which pull the material through the adjustable die, do not leave any marks on the surface of the rod.

✦ ✦ ✦

THE Straightening and Polishing Unit, as shown in the foreground, can be furnished separately, when it is used for straightening and polishing pre-cut rods or tubes of any length. The rod or tube, which is thrown into the machine, rotates rapidly between two pairs of polishing discs and at the same time gets straightened by passing through three off-set bushings mounted on ball-bearings. When the rod or tube leaves the machine, it is perfectly straight and highly polished. The separate straightening and polishing machine has different rates of speed and, therefore, different polishes are obtained. It is claimed that the polishing operation improves the surface of the rod and eliminates irregularities, without changing the diameter of the rod. The machine, which is also suitable for giving a mirror-like polish to turned or ground rods and shafting, is furnished in three sizes for handling 1/16-1¼ in. diameter rods or tubes.

✦ ✦ ✦

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FOLDED PAPER FLATS
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E. W. TWITCHELL, INC.
Formerly National Patent Reed Co.
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William C. Grader

FUNERAL services were held recently for William C. Grader, 65 years old, superintendent of the Cleveland Wire Spring Company, who died after a brief illness. Mr. Grader who was born in Cleveland, had been associated with the Cleveland Wire Spring Company for 36 years.

✦ ✦ ✦

Carboloy Reports Sales Increase

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New York

BUYERS' GUIDE

For more complete information, consult the annual Directory, Index & Buyers' Guide.

ABRASIVES—
Norton Co., Worcester, Mass.

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Scudder, E. J., Fdry. & Machine Co., Trenton, N. J.

ARMORING EQUIPMENT
Amer. Insulating Mach'y Co., Phila., Pa.
New England Butt Co., Providence, R. I.
Sleeper & Hartley, Inc., Worcester, Mass.
Watson Machine Co., Paterson, N. J.

BAKERS
Morgan Construction Co., Worcester, Mass.
Morrison Engineering Co., Cleveland, O.
Vaughn Machinery Co., Cuyahoga Falls, O.

BORON CARBIDE—
Norton Co., Worcester, Mass.

CEMENTS—Refractory
Norton Co., Worcester, Mass.

CHEMICALS—Cleaning
American Chemical Paint Co., Ambler, Pa.
American Machine & Foundry Co., Amaloy Div., Brooklyn, N. Y.
Delany Chemical Co., Tacony Station, Philadelphia, Pa.
Parkin Co., The Wm., Pittsburg, Pa.

CLEANING & PICKLING EQUIPMENT
Broden Construction Co., Cleveland, O.
Duriron Co., The, Dayton, O.
Morgan Construction Co., Worcester, Mass.
Nukem Products Corp., Buffalo, N. Y.
Vaughn Machinery Co., Cuyahoga Falls, O.

COATING—Protective
American Lanolin Corp., Lawrence, Mass.

COILERS—Sheet, Strip and Wire
Borden Construction Co., Cleveland, O.
Farrel-Birmingham Co., Inc., Ansonia, Conn.
H. J. Ruesch Machine Co., Newark, N. J.

CONDUITS—Iron and Steel
Youngstown Sheet & Tube Co., Youngstown, Ohio.

CRANES—Wire Mill
Cleveland Electric Tramrail Div., of Cleveland Crane & Eng. Co., Cleveland, O.
Morgan Construction Co., Worcester, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.

DIES—Diamond
Balloffet Diamond Wire Dies Co., Inc., N. Y. C.
Cochaud Wire Die Co., New York.
Kelly Wire Die Corp., New York, N. Y.
Union Wire Die Corp., New York, N. Y.
Vianney Wire Die Works, New York.

DIES—Lead Extrusion
John Robertson Co., Brooklyn, N. Y.

DIES—Repairs & Re-Cutting
Cochaud Wire Die Corp., New York.
Firth-Sterling Steel Co., McKeesport, Pa.
Kelly Wire Die Corp., New York. N. Y.
Union Wire Die Corp., New York, N. Y.
Vianney Wire Die Wks., N. Y.

DIES—Rod and Tube Drawing
Bissett Steel Co., Div. of Tungsten Electric Co., Cleveland, O.
Carboloy Co., Inc., Newark, N. J.
Firth-Sterling Steel Co., McKeesport, Pa.
Kelly Wire Die Corp., New York, N. Y.
Union Wire Die Corp., New York, N. Y.
Vianney Wire Die Works, New York, N. Y.

DIES—Tantalum Carbide
Bissett Steel Co., Div. of Tungsten Electric Co., Cleveland, O.
Kelly Wire Die Corp., New York, N. Y.
Vianney Wire Die Works, New York, N. Y.

DIES—Tungsten Carbide
Bissett Steel Co., Div. of Tungsten Electric Corp., Cleveland, O.
Carboloy Co., Inc., Newark, N. J.
Firth-Sterling Steel Co., McKeesport, Pa.
Kelly Wire Die Corp., New York, N. Y.
Union Wire Die Corp., New York, N. Y.
Vianney Wire Die Works, New York, N. Y.

DRAW BENCHES
H. J. Ruesch Machine Co., Newark, N. J.
Scudder, E. J., Fdry. & Machine Co., Trenton, N. J.
Vaughn Machinery Co., Cuyahoga Falls, O.

ENGINEERS—Consulting Galvanizing
W. H. Spowers, Jr., New York, N. Y.

ENGINEER—Consulting Wire Mill
Lewis, Kenneth B., New York, N. Y.

ENGINEERS—CONSULTING—Non-ferrous Wire Mill
New Products Development Corp., Yonkers, N. Y.

EYELETS—Brass or Zinc
Platt Bros. & Co., The, Waterbury, Conn.

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FURNACES—Annealing
Electric Furnace Co., Salem, O.
Surface Combustion Co., Toledo, O.

FURNACES—Automatic
Electric Furnace Co., Salem, O.
Surface Combustion Co., Toledo, O.

FURNACES—Bright Annealing
Electric Furnace Co., Salem, O.
Surface Combustion Co., Toledo, O.

FURNACES—Electric
Electric Furnace Co., Salem, O.
Surface Combustion Co., Toledo, O.

FURNACES—Lead Melting
Electric Furnace Co., Salem, O.
John Robertson Co., Brooklyn, N. Y.
Surface Combustion Co., Toledo, O.

FURNACES—Non-Oxidizing
Electric Furnace Co., Salem, O.
Surface Combustion Co., Toledo, O.

FURNACES—Wire, Strip and Sheet
Electric Furnace Co., Salem, O.
Surface Combustion Co., Toledo, O.

GEARS—Wire Mill
Lewis Foundry & Machine Co., Pittsburgh, Pa.

GRINDERS—Roll
Norton Co., Worcester, Mass.

HANDLING EQUIPMENT—Material
Cleveland Electric Tramrail, Div. of Cleveland Crane & Eng. Co., Wickliffe, O.

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American Chemical Paint Co., Ambler, Pa.
Delany Chemical Co., Tacony Station, Philadelphia, Pa.
Parkin Co., The Wm., Pittsburgh, Pa.

INSULATION—Cable or Cable Filler
E. W. Twitchell, Inc., Phila., Pa.

LATHES—Die Reaming
Morgan Construction Co., Worcester, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.

LIME—Pulverized
Amer. Lime & Stone Co., Bellefonte, Pa.

LINING FOR ACID TANKS—
Nukem Products Corp., Buffalo, N. Y.

LUBRICANTS—Wire Drawing
American Machine & Foundry Co., Amaloy Div., Brooklyn, N. Y.
R. H. Miller Co., Homer, N. Y.
J. T. Robertson & Co., Syracuse, N. Y.

MACHINERY—Armoring (Cable, Wire Hose)
American Insulating Mach'y Co., Phila., Pa.
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John Robertson Co., Brooklyn, N. Y.
Saylor, F. D. & Son, Detroit, Mich.
Sleeper & Hartley, Inc., Worcester, Mass.
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Braiding
New England Butt Co., Providence, R. I.
Saylor, F. D. & Son, Detroit, Mich.
Watson Machine Co., Paterson, N. J.

MACHINERY—Brazing
Thomson-Judd Wire Machinery Co., Lynn, Mass.

MACHINERY—Bunching
Amer. Insulating Mach'y Co., Phila., Pa.
New England Butt Co., Providence, R. I.
Sleeper & Hartley, Inc., Worcester, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Bundling, Scrap
Sleeper & Hartley, Inc., Worcester, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.
Watson Machine Co., Paterson, N. J.

MACHINERY—Cable, Electric
American Insulating Machinery Co., Philadelphia, Pa.
New England Butt Co., Providence, R. I.
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Watson Machine Company, Paterson, N. J.

MACHINERY—Chain Making
Vaughn Machinery Co., Cuyahoga Falls, O.

MACHINERY—Closing
New England Butt Co., Providence, R. I.
Watson Machine Co., Paterson, N. J.

MACHINERY—Coil Winding
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Coilers
Broden Const. Co., Cleveland, O.
Morgan Const. Co., Worcester, Mass.
H. J. Ruesch Machine Co., Newark, N. J.
Sleeper & Hartley, Inc., Worcester, Mass.
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.
Watson Machine Co., Paterson, N. J.

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H. J. Ruesch Machine Co., Newark, N. J.
Vaughn Machinery Co., Cuyahoga Falls, O.
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.

MACHINERY—Covering Wire—
Saylor, F. D. & Son, Detroit, Mich.
Syncro Machine Co., Newark, N. J.

MACHINERY—Cutting
Broden Construction Co., Cleveland, O.
Hallden Machine Co., Thomaston, Conn.
F. B. Shuster Co., New Haven, Conn.
W. A. Schuyler, New York, N. Y.
Sleeper & Hartley, Worcester, Mass.

MACHINERY—Enameling
American Insulating Mach'y Co., Phila., Pa.

MACHINERY—Extruding
John Robertson Co., Brooklyn, N. Y.
Watson Machine Co., Paterson, N. J.

MACHINERY—Flat Wire
Broden Construction Co., Cleveland, O.
H. J. Ruesch Machine Co., Newark, N. J.
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Forming
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Galvanizing Wire
Broden Construction Co., Cleveland, O.
Sleeper & Hartley, Inc., Worcester, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.

MACHINERY—Gang Winders
H. J. Ruesch Machine Co., Newark, N. J.
Watson Machine Co., Paterson, N. J.

MACHINERY—Grinding
Norton Co., Worcester, Mass.

MACHINERY—Insulating
American Insulating Machinery Co., Phila.
New England Butt Co., Providence, R. I.
Saylor, F. D. & Son, Detroit, Mich.
Syncro Machine Co., Newark, N. J.
Watson Machine Co., Paterson, N. J.

MACHINERY—Lead Encasing Presses, etc.
John Robertson Co., Brooklyn, N. Y.

MACHINERY—Lead Stripping
John Robertson Co., Brooklyn, N. Y.
Watson Machine Co., Paterson, N. J.

MACHINERY—Lock Washer
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Magnet Wire
American Insulating Mach'y Co., Phila., Pa.
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Material Handling
Cleveland Electric Tramrail Div. of Cleveland Crane & Engineering Co., Wickliffe, Ohio.

MACHINERY—Measuring Wire & Cable
Davis Electric Corp., Wallingford, Conn.
New England Butt Co., Providence, R. I.
Watson Machine Co., Paterson, N. J.

MACHINERY—Nail and Tack
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Panning
American Insulating Machinery Co., Phila.

MACHINERY—Pointing
Broden Construction Co., Cleveland, O.
H. J. Ruesch Machine Co., Newark, N. J.
E. J. Scudder Foundry & Machine Co., Trenton, N. J.
Sleeper & Hartley, Inc., Worcester, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.

BUYERS' GUIDE, Continued

MACHINERY—Rod Mill
Broden Construction Co., Cleveland, O.
Lewis F'dry & Machine Co., Pittsburgh, Pa.
Morgan Const. Co., Worcester, Mass.
H. J. Ruesch Machine Co., Newark, N. J.
W. A. Schuyler, New York, N. Y.

MACHINERY—Rolling Mill
Broden Construction Co., Cleveland, O.
Lewis F'dry & Machine Co., Pittsburgh, Pa.
Morgan Construction Co., Worcester, Mass.
H. J. Ruesch Machine Co., Newark, N. J
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.

MACHINERY—Rubber Strip Covering
New England Butt Co., Providence, R. I.
Watson Machine Co., Paterson, N. J.

MACHINERY—Rubber Tubing and Straining
New England Butt Co., Providence, R. I.
Sleeper & Hartley, Inc., Worcester, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Screw Wire
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Special
American Insulating Mach'y Co., Phila. Pa.
Broden Construction Co., Cleveland, O.
H. J. Ruesch Machine Co., Newark, N. J.
E. J. Scudder Foundry and Machine Co., Trenton, N. J.
Sleeper & Hartley, Inc., Worcester, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Special—Combination Machine for Drawing, Cutting-to-length, Straightening and Reeling Bars from Coil in One Operation (Shumag Type)—
W. A. Schuyler, New York, N. Y.

MACHINERY—Spooling
American Insulating Machinery Co., Phila.
Vaughn Machinery Co., Cuyahoga Falls, O.
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.
Watson Machine Co., Paterson, N. J.

MACHINERY—Spring Making
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Staple
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Straightening
Broden Construction Co., Cleveland, O.
Hallden Machine Co., Thomaston, Conn.
H. J. Ruesch Machine Co., Newark, N. J.
W. A. Schuyler, New York, N. Y.
F. B. Shuster, New Haven, Conn.
Sleeper & Hartley, Inc., Worcester, Mass.

MACHINERY—Stranding
New England Butt Co., Providence, R. I.
Sleeper & Hartley, Inc., Worcester, Mass.
Thomson-Judd Wire Machinery Co., Lynn, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Strip Steel
Broden Const. Co., Cleveland, O.
Lewis F'dry & Machine Co., Pittsburgh, Pa.
H. J. Ruesch Machine Co., Newark, N. J.

MACHINERY—Swaging
H. J. Ruesch Machine Co., Newark, N. J.
Sleeper & Hartley, Worcester, Mass.
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.

MACHINERY—Taping
Amer. Insulating Mach. Co., Phila., Pa.
New England Butt Co., Providence, R. I.
Thomson-Judd Wire Machinery Co., Lynn, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Testing Size of Wire
R. L. Davis Elec. Co., Wallingford, Conn.

MACHINERY—Tinsel Rolling Mills
Amer. Insulating Mach'y Co., Phila., Pa.

MACHINERY—Trolley Wire
Vaughn Machinery Co., Cuyahoga Falls, O.

MACHINERY—Tube Mill
H. J. Ruesch Machine Co., Newark, N. J.

MACHINERY—Welding Wire
Micro Products Co., Chicago, Ill.
F. B. Shuster Co., New Haven, Conn.
Thomson-Judd Wire Machinery Co., Lynn, Mass.

MACHINERY—Winding
American Insulating Mach'y Co., Phila., Pa.
New England Butt Co., Providence, R. I.
Sleeper & Hartley, Inc., Worcester, Mass.
Watson Machine Co., Paterson, N. J.

MACHINERY—Wire Drawing
American Insulating Machinery Co., Phila.
Broden Const. Co., Cleveland, Ohio.
Morgan Construction Co., Worcester, Mass.
H. J. Ruesch Machine Co., Newark, N. J.
E. J. Scudder Foundry & Machine Co., Trenton, N. J.
W. A. Schuyler, New York, N. Y.
Sleeper & Hartley, Inc., Worcester, Mass.
Thomson-Judd Wire Machinery Co., Lynn, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.
Waterbury-Farrel Foundry & Machine Co., Waterbury, Conn.

MACHINERY—Wire Rope
New England Butt Co., Providence, R. I.
Thomson-Judd Wire Machinery Co., Lynn, Mass.
Watson Machine Company, Paterson, N. J.

MACHINERY—Wire Tinning
American Insulating Mach'y Co., Phila., Pa.

MACHINERY—Wrapping Wire
W. A. Schuyler, New York, N. Y.

MATERIAL HANDLING EQUIPMENT—
Cleveland Electric Tramrail Div., of Cleveland Crane & Eng. Co., Cleveland, O.

PAPER—Insulating
E. W. Twitchell, Inc., Phila., Pa.

PICKLING COMPOUNDS—
American Chemical Paint Co., Ambler, Pa.
Delany Chemical Co., Tacony Station, Philadelphia, Pa.
Parkin Co., The Wm., Pittsburgh, Pa.

PICKLING TANK LINING—
Nukem Products Corp., Buffalo, N. Y.

POTS—Lead Melting
John Robertson Co., Brooklyn, N. Y.

PRESSES—Hydraulic and Mechanical
John Robertson Co., Brooklyn, N. Y.

PRESSES—Lead Encasing
John Robertson Co., Brooklyn, N. Y.

PRESSES—Lead Extrusion
John Robertson Co., Brooklyn, N. Y.

PULLERS—Wire
E. J. Scudder Fdry. & Machine Co., Trenton, N. J.
Sleeper & Hartley, Inc., Worcester, Mass.

PUMPS—Hydraulic
John Robertson Co., Brooklyn, N. Y.

REEL AND TENSION STAND—
Sleeper & Hartley, Inc., Worcester, Mass.

REEL CRUTCHES
Watson Machine Co., Paterson, N. J.

REFRACTORIES—High Temperature
Norton Co., Worcester, Mass.

ROD BAKERS—
Morrison Engineering Co., Cleveland, O.

RODS—Wire—Non Ferrous
Hudson Wire Co., Ossining, N. Y.
Platt Bros. & Co., The, Waterbury, Conn.
Seymour Mfg. Co., Seymour, Conn.

RODS—Wire—Steel
Bethlehem Steel Co., Bethlehem, Pa.
Continental Steel Corp., Kokomo, Ind.
Keystone Steel & Wire Co., Peoria, Ill.
Republic Steel Co., Youngstown, O.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, Ohio.

ROLLING MILLS—See Machinery—Rolling Mill

ROLLS—
Lewis F'dry & Machine Co., Pittsburgh, Pa.

RUST PROOF COMPOUND
American Lanolin Co., Lawrence, Mass.

SHEET—Steel
Continental Steel Corp., Kokomo, Ind.
Republic Steel Co., Youngstown, O.
Superior Sheet Steel Co., Canton, O.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, O.

SOAPS—Wire Drawing
R. H. Miller Co., Homer, N. Y.
J. T. Robertson & Co., Syracuse, N. Y.

STRIP—Brass, Zinc and Non Ferrous
Hudson Wire Co., Ossining, N. Y.
Platt Bros. & Co., The, Waterbury, Conn.

STRIP—Steel
Bethlehem Steel Co., Bethlehem, Pa.
Continental Steel Corp., Kokomo, Ind.
Firth-Sterling Steel Co., McKeesport, Pa.
Republic Steel Co., Youngstown, O.
Wheeling Steel Corp., Wheeling, W. Va.

TANKS—Compound
Watson Machine Co., Paterson, N. J.

TREADS—Safety
Norton Co., Worcester, Mass.

TRUCKS
Morgan Construction Co., Worcester, Mass.
Vaughn Machinery Co., Cuyahoga Falls, O.

TUBE BENDERS AND FORMERS
H. J. Ruesch Machine Co., Newark, N. J.

VALVES AND FITTINGS—Acid Proof
Duriron Co., The, Dayton, O.

VULCANIZERS
Watson Machine Co., Paterson, N. J.

VULCANIZING PANS
American Insulating Mach'y Co., Phila., Pa.

WIRE—Cold Heading
Bethlehem Steel Co., Bethlehem, Pa.
Continental Steel Corp., Kokomo, Ind.
Keystone Steel & Wire Co., Peoria, Ill.
Republic Steel Corp., Youngstown, O.
Youngstown Sheet & Tube Co., Youngstown, O.
Wheeling Steel Corp., Wheeling, W. Va.

WIRE—Electric
Hudson Wire Co., Ossining, N. Y.

WIRE—Enameled For Coils
Winsted Div. of Hudson Wire Co., Winsted, Conn.

WIRE—Manufacturers
Bethlehem Steel Co., Bethlehem, Pa.
Continental Steel Co., Kokomo, Ind.
Keystone Steel & Wire Co., Peoria, Ill.
Republic Steel Co., Youngstown, O.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, Ohio

WIRE—Nickel Silver and Phosphor Bronze
Hudson Wire Company, Ossining, N. Y.

WIRE—Non Ferrous to Specification For Special Purposes
Hudson Wire Co., Ossining, N. Y.
Winsted Div. of Hudson Wire Co., Winsted, Conn.

WIRE—Spring
Bethlehem Steel Co., Bethlehem, Pa.
Continental Steel Corp., Kokomo, Ind.
Keystone Steel and Wire Co., Peoria, Ill.
Republic Steel Co., Youngstown, O.
Youngstown Sheet & Tube Co., Youngstown, Ohio.

WIRE—Steel—Also Coppered Steel—Also Galvanized Steel
Bethlehem Steel Co., Bethlehem, Pa.
Continental Steel Corp., Kokomo, Ind.
Keystone Steel & Wire Co., Peoria, Ill.
Republic Steel Co., Youngstown, O.
Wheeling Steel Corp., Wheeling, W. Va.
Youngstown Sheet & Tube Co., Youngstown, Ohio.

WIRE AND STRIP—Brass, Zinc
Platt Bros. & Co., The, Waterbury, Conn.

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ESTABLISHED 1845

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ELECTRIC PATCH VULCANIZERS	
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WIRE TINNING MACHINES	Gas fired and Electrical.
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SPOOLS	Heavy-duty for Rope-Mills and Cable-plants.

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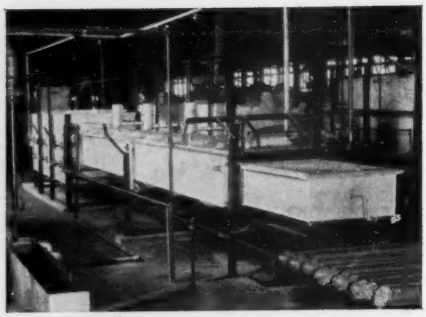
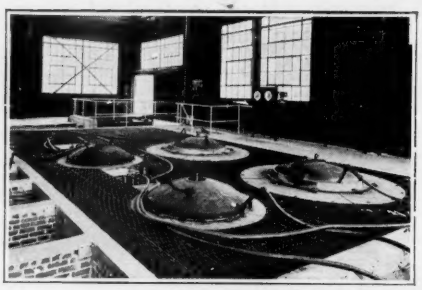


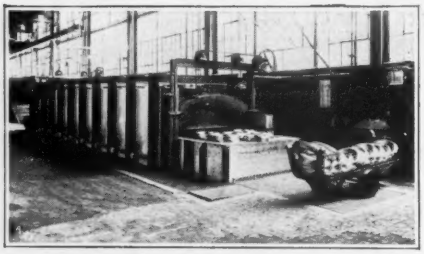
Bright Annealing Copper Wire

Fine copper wire is bright annealed, continuously, in the continuous, controlled atmosphere furnace shown at left. No vapor or water seals of any kind are used in this equipment—the wire comes out uniformly annealed, bright and dry, ready for shipment or further processing.

Bright Annealing Steel Wire

A pit type installation with Elfurno gas generator for annealing steel wire in coils is shown at right. Advantages include increased tonnage per pit, improved fuel economy, more uniformly annealed wire, lower maintenance cost, decreased annealing time and labor requirements and maximum flexibility—will produce bright surface, semi-bright or otherwise as required.



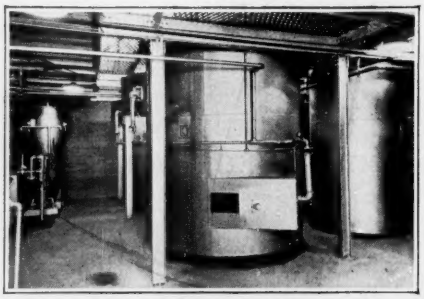


Clean Annealing Brass Wire

The continuous, gas-fired, controlled atmosphere furnace shown at left was built for a prominent brass and copper company for clean annealing brass and bronze wire in coils. The wire is carried through on continuous alloy chains spaced to carry both large and small coils. The furnace handles 5000 pounds per hour, and according to the purchaser "produces a high quality, low cost anneal with very good finish." Another similar installation has just been made.

Normalizing and Spheroidizing Rod

Fuel-fired, pit furnaces of the type shown at right have been installed for clean normalizing and spheroidizing rod, as well as annealing low carbon steel wire in coils. Low operating and maintenance cost, greater uniformity and ease of handling are some of the advantages of these fuel-fired pits—they can be either gas or oil-fired.



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